SILVICULTURAL RESEARCH MANUAL

FOR USE IN

INDIA

Vol. II.

STATISTICAL RESEARCH

(THE STATISTICAL CODE)

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PREFACE.

In Volume I of this Manual, the underlying general principles of silvicultural research have been surveyed, and their application to the classes of problems which are not primarily concerned with matters and methods of forest mensuration has been dealt with and exemplified. An historical note has been added, also covering the whole field.

The present volume provides for that side of experimental research which depends largely on the application of forest mensuration methods to the solution of problems, i.e., the side which deals mainly with the measurement of trees and crops. A considerable variety of problems can only be satisfactorily dealt with along these statistical lines, as although qualitative results are commonly apparent to the eye or to reason, quantitative data must also be determined to establish whether the results are of practical economic importance or not. Thus methods of raising plantations and of thinning, determination of rotation, the effects of fire, grazing and insect attack—all require to be studied on similar lines.

The greater part of the procedure described in this second volume has been standardised for general use throughout India and Burma, having been accepted by the Silvicultural Conference of 1929. The important chapter dealing with sample plots for crop increment continues the procedure which has been the standard one since the Silvicultural Conference of 1918. This procedure was described by Mr. Howard in his "Code for the Collection and Tabulation of Statistical Data" and was adapted from Dr. Schwappach's method as used by the Prussian Research Institute, with certain modifications (not all on too sound a theoretical basis) to suit Indian conditions. The method of presentation has, however, been entirely recast.

The outline of the methods for collecting data for volume tables also follows closely that hitherto in use.

In nearly all cases the procedure has been submitted to special field tests and critical examination before acceptance for this Code, with a view to keeping all prescriptions as severely practical and simple for use in the field as is possible with due regard to ensuring the degree of accuracy demanded of the end results. Comments have been inserted

wherever needed, and attention has been directed to points requiring further study.

The following chapters are the joint work of the two authors, the first draft having been written sometimes by one and sometimes by the other, and then subjected to successive revisions in the same way. In general, however, the senior author is primarily responsible for the framework, method of presentation and editing, whilst the junior author has especially dealt with the mathematical aspects of the problems considered and the working up of the examples.

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Introduction to Volume II.

The separate treatment of the statistical side of silvicultural research is easy to justify, provided it is clearly borne in mind that it is only an appendix to the general principles of experimentation as given in Vol. I of this Manual. In other words, statistical methods are to be viewed as an additional and very valuable instrument for investigation of the biological problems we are called upon to deal with in forestry.

In the first instance, the collection of forest statistics is definitely not experimental; the immediate object in view is to collect data as we find them offered to us, rather than to follow the results of varying the controllable factors. Forestry, however, shares the characteristic of all biological sciences that the data so collected are never truly uniform, varying not only from the limitations of accuracy in observing and recording, but with each individual examined. Some sort of analysis is always a necessary preliminary to the application of the data to specific cases, and this analysis constitutes one of the fundamental principles of experimental research.

All the statistical data the forest officer deals with are averages, and in a general way, the greater the bulk of data from which the averages are derived, the more reliable such averages are. It therefore becomes of importance to follow a standardised procedure in taking and recording measurements to ensure comparability permitting of combination. Hence the acceptance of a prescribed Code of procedure for much of this work, in contrast with what are mainly suggestions for the definitely experimental side.

This standard procedure then becomes available for application to definitely experimental work in comparing the reaction of the forest to variation of more or less controllable variables. In the long run, the importance of all factors influencing the forest depends on their effect direct or indirect on crop increment, so that the accurate measurement of crop increment becomes a matter of the greatest importance to the investigator. Measurement of single tree increment is involved in the procedure for determining crop increment, and has sometimes to be substituted as a tentative measure for crop increment.

The problems to be dealt with are accordingly classified as follows :—

I. Investigations connected with determination of Single Tree Volume.

(*a*) Volume Tables (Chapter III).

(*b*) Outturn Tables and Assortment Tables (Chapter III).

(*c*) Conversion Factors, etc. (Chapter IV).

II. Investigations connected with determination of Crop Volume.

(*a*) Enumerations and Stand Tables (Chapter V).

III. Investigations connected with determination of Single Tree Increment.

(*a*) Tree Increment Plots (Chapter VI).

(*b*) Stump Analysis (Chapter VII).

(*c*) Stem Analysis (Chapter VIII).

(*d*) Increment Borings (Chapter IX).

IV. Investigations connected with determination of Crop Increment.

(*a*) (Crop Increment) Sample Plots for even-aged crops (Chapters X, XI).

(*b*) Yield Tables (Chapter XII).

(*c*) Increment of Irregular Forest.

All of these investigations may be an end in themselves, but they generally have a further aim in the elucidation of the effects of one or more of the following influences :—

(1) Seedling or coppice origin.

(2) Artificial or natural reproduction.

(3) Variations in artificial reproduction.

(4) Variations in thinning procedure.

(5) External dangers (fires, grazing, erosion of soil, irrigation, drainage, underplanting, and insect attack).

The general methods to be applied will be the same in all cases, as given in the following chapters, and any special points with regard to each are mentioned in Part II of Vol. I under the appropriate heads.

The first chapter deals briefly with the essential mathematical processes involved in developing the field data collected in the course of statistical investigations, and also to an appreciable extent in determining what data require to be collected.

What should have been the last chapter, dealing with the increment of uneven-aged forest, has been omitted for the present as adequate testing has not yet been found practicable.

Photo. H. G. Champion.

Sample Plot in a teak plantation : Quality I, age 38 years, crop height 92 ft., crop diameter 11·5 ins.
Plot 9, Tharawaddy division, Burma.

Frontispiece.

SILVICULTURAL RESEARCH MANUAL

CHAPTER I.

The Mathematical Principles Utilised.

[NOTE.—This chapter does not aim at presenting a comprehensive or systematic treatment of the use of statistical methods in forestry; it is devoted to a brief description of the more familiar methods employed for the statistical reduction of such data as are obtained in the course of taking measurements on trees and crops, with the object of deriving the figures required to specify the data adequately and to measure the precision of results obtained by sampling. For much of the data usually collected, the graphic method is the one which is generally used, at any rate in the early stages of compilation, and for this reason, suggestions are given only for the graphic working up of such data.]

(i) THE AVERAGE.

The three kinds of averages dealt with here are :—

(1) *Arithmetic average,* which is computed as the sum of a series of values divided by the number of values summed. In computing the average of grouped data, each value is multiplied by the number of times it occurs in the series (the frequency), and the products are summed.

*Ex. 1. *Diameter in inches*	15	16	17	18	19
Frequency	3	4	6	3	2

Arithmetic Average $= \dfrac{15\times3+16\times4+17\times6+18\times3+19\times2}{3+4+6+3+2}$

$$=\frac{303}{18}$$

$$=16{\cdot}8$$

(2) *Weighted arithmetic average.*—Weighted arithmetic average differs from the ordinary arithmetic average in that to obtain the former, each value in the series is multiplied before summation by a number which represents not its frequency, but a measure of the weight or importance of its contribution to the sum.

Ex. 2. *Where* p_1, p_2, p_3 *are growth per cent. in volume of different diameter classes, and* V_1, V_2, V_3 *are volumes of these diameter classes : Average growth per cent. is given by :—*

$$P=\frac{V_1\,p_1+V_2\,p_2+V_3\,p_3}{V_1+V_2+V_3}$$

(3) *Moving averages.*—These are computed by taking two or more values at a time successively for the whole series, and averaging them as for arithmetic averages.

Ex. 3. *Diameters*	20	27	22	35	24	22	17	24
Moving averages of groups of 3 diameters	..	23	28	27	27	21	21	..

[*Here* 23=⅓ (20+27+22) ; 28=⅓ (27+22+35) ; *etc.*

* To make the examples simple, as small a number of values as possible has been utilised even where the principle involved is inapplicable to such a small number.

The object of computing moving averages is to rid the data of minor fluctuations which obscure the general trend in drawing a curve through the points.

(ii) MEASURES OF DISPERSION.

The only measures of dispersion referred to in the following chapters are :—

(1) *Average deviation of a single observation.*—This measures the average deviation of each measurement from the mean of the whole series, and is computed as the sum of the deviations (irrespective of sign) of the several values in the series from the arithmetic average, divided by the number of values.

Ex. 4. *Values*	5	7	8	12	14	20
Total	66					
Average	$=\frac{66}{6}=11$					
Deviation from average	6	4	3	1	3	9
Total	26					
Average deviation	$=\frac{26}{6}=4{\cdot}3$					

(2) *Standard Deviation of a single observation* (*S. D.*).—The deviations of a set of measurements from the mean can be arranged by magnitude in an ascending series. The *Standard Deviation* is the value of the deviation (positive or negative) which is exceeded by only one third of the values. It is most conveniently computed by summing the deviations, irrespective of sign, and multiplying by a factor dependent on the number of values.

This factor F_1 is actually $\frac{1{\cdot}2532}{\sqrt{n(n-1)}}$, n being the number of values, and it can be read directly from the table on p. 245, Appendix VI.

Ex. 5. *As a result of stump analysis of 12 deodar trees, the following stump diameters were recorded corresponding to 120 rings on each of the stumps.*

Stump diameters in inches .	26·75, 15·58, 21·78, 10·90, 13·98, 12·23, 19·23, 19·93, 16·98, 16·05, 19·63, 16·08.
Total	=209·12
Number of values . . .	=12
Average	=17·43 .
Deviations from 17·43 . .	=9·32, 1·85, 4·35, 6·53, 3·45, 5·20, 1·80, 2·50, 0·45, 1·38, 2·20, 1·35.
Sum of deviations . . .	=40·38
(*Average deviation* . . .	=3·365)
F_1 *from the table* . . .	=·1091
Standard deviation . . .	=40·38 × ·1091 =4·41.

The practical utility of S. D. lies in the fact that ordinarily* it and the mean together completely describe the whole series of values. As only about 5 per cent. of the observations or measurements will deviate from the mean by more than

* The necessary condition is that the values are normally distributed about the mean, and so conform to the theory of Normal Frequencies.

twice the S. D., this range is usually accepted as the *limit of significance*, in that variations exceeding it cannot be accepted as due to the causes which are responsible for the variation up to these limits within the series.

Ex. 6. *In the example of stump analysis data given above as Example 5, the average stump diameter of 17·43 with a S. D. of 4·41 means that two-thirds of the total number of measurements lie within the limits 21·84 and 13·02, only the remaining third lying beyond these limits.* [17·43+4·41=21·84 ; 17·43—4·41=13·02.]

Ex. 7. *Referring to the same data again, measurements beyond the range (Mean ±2 S. D.) or (17·43±2×4·41), and so smaller than 8·61 or larger than 26·25, may be rejected ; average stump diameter would then be calculated on the basis of the remaining values only. In this example one measurement, namely 26·75, will be rejected ; the revised mean becomes 16·58 and the new standard deviation 3·49, no single deviation exceeding twice this figure.*

(iii) Standard Error of a mean.

The standard error (S. E.) of the mean itself is equal to the standard deviation of the individual observations, divided by the square root of the number of observations. To obtain standard error, it is not necessary to apply this formula, as tables are given on p. 245 for a factor F_2 which has only to be multiplied by the sum of the deviations (irrespective of sign).

This factor F_2 is actually $\frac{1{\cdot}2532}{n\sqrt{(n-1)}}$ where n is the number of values.

Ex. 8. *Required the Standard Error of the mean of a series of ten stump diameters corresponding to 120 rings.*

Diameters . .	17·20, 20·30, 23·40, 13·80, 20·33, 15·88, 19·15, 19·18, 22·98, 13·90.
Total . . .	=186·12
Mean . . .	=18·61
Deviations . .	1·41, 1·69, 4·79, 4·81, 1·72, 2·73, 0·54, 0·57, 4·37, 4·71
Sum of deviations .	=27·34
F_2 from table .	=0·0418
Standard Error .	=0·0418×27·34=1·14

(iv) Sampling.

By *sampling* is meant the examination of a large group by means of a representative small group or *sample*, the results of such examination of the sample being then generalised for application to the larger group.

The chief obstacle in the way of satisfactory sampling is the observer himself, i.e., his personal bias (often unconscious) which in its extreme form may be due to a desire to find evidence in support of a favourite hypothesis. A direct method of eliminating personal bias, at any rate theoretically, consists in laying down the way the samples should be selected. The most usual condition is that they should be taken purely at random, and that their number should be adequate.* A further improvement in sampling, particularly in the case of the very large group, can usually be effected by first subdividing it into a number of appropriate sub-groups and taking random samples in each of these.

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* This is based on the Theory of Probabilities according to which if an adequate number of samples are chosen at random from a large group or "universe" as it is called, their average is almost sure to agree with that of the whole group (i.e., with the "*true mean*").

In the case of forest statistics, sampling is very generally essential on account of the great number of trees and large areas dealt with, so that for nearly all data, a suitable sampling procedure must be decided before work can proceed in the field. The general principles of sampling are set down in the following paragraphs, and numerous instances of application will be met with in the subsequent chapters.

(*a*) The number of samples should be as large as possible, i.e., the larger the number of sample trees, or the greater the area covered, the better.

(*b*) It is desirable to take samples separately for a number of appropriate subdivisions such as diameter, height, crown, or form quotient classes, quality classes, or area subdivisions.

(*c*) The arrangement of the samples should be entirely at random, or on a mechanical basis suited to the nature of the material and the investigation.

Ex. 9. *In the case of Pressler borings, borings might be taken on every third tree in a series of parallel rows; when enumerating, the area might be covered in strips at a convenient spacing; when investigating a series of controllable variables, plots might be arranged in a Latin square (see Vol. 1, Part 1, Section VIII (iv)).*

(v) Precision of arithmetic average.

The arithmetic average of a sample provides the best representative value for a whole series, as may be established on the basis of the theory of least squares (*1*, p. 22)* or the normal error law (*1*, p. 22). However, the fact must not be forgotten that the degree of confidence to be placed in these averages is not uniform, and is measured by the standard error. The precision, being the converse of the S. E., varies directly as the square root of the number of observations from which it is derived, so that in considering an average by itself, or in comparison with another, a knowledge of the number of observations is essential for evaluating the precision attained.

Ex. 10. *In Example 8, the average and the S. E. calculated from the data from 10 stumps are 18·61" and 1·14" respectively. If a greater number of measurements are taken, say 41, a smaller S. E. of 0·6" is obtained; marked improvement in precision has been gained, the limits within which the true mean lies having been reduced from ±1·14 to ±0·6.*

(vi) Computation of the number of observations required for a given degree of accuracy.

The determination of the number of observations required for a given degree of accuracy is based on the application of the relationship between the standard deviation of individual observations and the standard error of the mean.

$$\text{S. E.} = \frac{\text{S. D.}}{\sqrt{n}}, \text{ whence } n = \left(\frac{\text{S. D.}}{\text{S. E.}}\right)^2$$

S. D. is directly calculated from the data as explained above, and S. E. is determined by the desired accuracy in results; i.e., the maximum permissible limit of error which corresponds to the range 2×S. E. on either side of the mean; S. E. therefore equals half the permissible limit of error.

* References to literature will be found at the end of the Code on p. 243.

(It is often convenient to compute S. E. after collecting a portion of the data, to determine to what extent it is approximating the desired limit.)

Ex. 11. *The following diameter measurements were recorded corresponding to 120 rings on 13 deodar stumps. Required the number of trees necessary so that the resulting average diameter may be accurate to 0·5″.*

Diameters . . 20·43, 18·45, 16·50, 22·78, 21·30, 14·60, 17·63, 26·10, 17·70, 21·75, 11·35, 16·13, 19·42.

Total . . . =244·14

Average . . =18·78

Deviations from 18·78 . . 1·65, 0·33, 2·28, 4·00, 2·52, 4·18, 1·15, 7·32, 1·08, 2·97, 7·43, 2·65, 0·64.

Sum of deviations . =38·20

$\frac{F_1 \text{ from table}}{\text{S. D.}}$. =·1004

=38·20×·1004
=3·84

Maximum permissible limit, or error . =0·5″

Therefore S. E. . . $=\frac{0·5}{2}=0·25$

Required number of trees . . $=\left(\frac{\text{S. D.}}{\text{S. E.}}\right)^2=\left(\frac{3·84}{0·25}\right)^2=236.$

(vii) Curve Construction.

A.—Choice of scale.

With a curve well drawn on paper ruled in tenths of an inch, values can only be read to one quarter of the ruled units, i.e., to 1/40th of an inch, and to ½ mm. in the case of millimeter paper.

To determine the smallest scale which will give the desired closeness of reading, divide the latter (in whatever unit) by ¼ for 1/10″ paper and ½ for mm. paper, and the quotient is the number of units in 1/10″ or 1 mm. respectively.

Ex. 12. *If volumes are to be read correct to ½ c. ft. using 1/10″ paper, one square will scale 2 c. ft. (½÷¼), and 1″ will represent 20 c. ft. On mm. paper, 1 mm.=1 c. ft.*

B.—Plotting of averages for drawing a smooth curve.

It is usually easier to draw a curve over points plotted from group averages, than over the individual points, and this procedure is preferable. With exceptionally irregular data it may be helpful to plot "*moving averages*" (cf. p. 1).

C.—Plotting individual points.

When a point representing a group average appears badly off the general trend of the other points, it is often helpful to plot the individual values which together build the average, with a view to considering the possibility of the rejection of one or more exceptionally aberrant values responsible for the abnormal average.

D.—Rejection of observations.

No figure should be rejected except on very good grounds. The number rejected should be a small percentage of the total number, and the abnormalities should ordinarily balance as regards sign. Great caution is necessary, since a large deviation may either be due to some unusual source of error, or to the chance occurrence of a large number of small errors with the same sign; if the latter is the case, then rejection may diminish rather than increase the accuracy of the final results.

E.—Smoothing of curves.

The principle "*Natura non facit saltus*" is accepted in drawing growth curves. Sharp turns and double inflections are to be avoided unless reasonably explicable by physical factors. Curves should be drawn with the maximum radius of curvature continued over the longest possible stretch. The two processes known as smoothing and harmonising are utilised to help towards this end.

1. *Smoothing.*—By smoothing is meant graduation of the values of the dependent variable for series of equidistant values of the independent variable. If the observational errors are considerable, or the data scanty, then it is customary to draw smooth curves, not actually through the points, but evenly among them and as closely as possible to them, on the assumption that the actual function has no very rapid fluctuations. In smoothing, the weight of each point should be taken as the square root of the number of observations it represents.

2. *Harmonising.*—By harmonising is meant the graduating relatively to one another, of corresponding values in different classes into which a set of data is divided. In harmonising, the central portion of the central curve—being based on most observations—is taken as the basis, and the end portion of the curve next to this, which is generally based upon scanty data, corrected accordingly, this process being continued to the remotest curve.

The difference between smoothing and harmonising should be noticed; the former relates to values belonging to a single class and so to a single curve, the latter to values as between class and class, and so to a family of curves.

F.—Best fitting curves.

The term *best fit*, as applied to curves, customarily implies reference to the *theory of least squares* (*1*, p. 22). This method of determining the position of a curve with reference to a set of points requires that the sum of squares of the deviations of the observed values from the corresponding values read from the curve. is a minimum. For strict application, it would be necessary to find an equation for the curve, but this is not necessary with the type of data here in question, and the term "*best fit*" is used with reference to any reasonable limit of closeness of agreement between the observed data and the corresponding curved values, such as a percentage of the values concerned. The limit selected should be determined in each instance with reference to the intended practical application.

It should be remembered that any such comparison of the observed values with the corresponding values from the curves is applicable only to such portions of the curves as have an adequate basis in points.

A table of squares is given as Appendix IX on p. 251.

(viii) Graphic Interpolation.

(A) *Use of interpolation.*

Published tables and curves usually give values corresponding to definite points of age, usually decades, or the middle of diameter or height classes, etc. Sometimes also the basic data themselves represent discontinuous measurements or observations separated by an interval of time, etc. For several purposes, details of values intermediate between those given in the published tables and curves or the recorded observations are needed. To give estimates of such intermediate values is the purpose of interpolation.

(B) *Method of interpolation.*

Only the simplest methods of numerical or graphic interpolation will be required. Such are :—

1. *Simple graphic interpolation.*—When values are given at two or more points, representing only a small range or interval of age, or diameter, etc., estimates for any intermediate point may be interpolated on the assumption that the value varies continuously from point to point, and that the rate of change in value is uniform over this small range, *i.e.*, that variation can be represented by a straight line joining the points. If there is any reason to believe that the latter condition does not hold, a smooth curve may be drawn through the points representing known values, and the necessary intermediate value read off the curve.

2. *Graphic interpolation with the help of a subsidiary curve.*—When values available from curves correspond to the middle of diameter and height classes (in the general case, if they correspond to mid-class points of two independent variables), interpolation is most conveniently done by constructing a subsidiary curve based on actual diameters and height, super-imposed upon the original set of curves. A typical example will be found in the construction of local volumes curves, *see* p. 32.

Note.—Appendix XI on p. 256, gives commonly used constants and formulæ which should be helpful in connection with the processes described in this and the succeeding chapters.

Photo. H. G. Champion.

Sample Plot 9, S. Andamans division, in *Bruguiera gymnorhiza* ; crop height 109 ft., crop diameter 14·1 ins. Illustrating General Rule 6, the cross mark being put at 10 feet above ground level on account of buttress formation.

Opposite page 9.

CHAPTER II.

General Rules for Measurement of Trees.

(i) Breast height.

1. Breast height should be measured by means of a measuring stick on the standing tree at 4′ 6″ above ground level.

2. On sloping ground, breast height should be measured on the uphill side, after removal of any dead leaves and needles lodged there.

3. The breast height point should be marked by intersecting vertical and horizontal lines (5″ long) whenever possible, painted with white paint. This is referred to as the *cross mark*.

4. Breast height measurements should not be taken at 4′ 6″ if the stem is abnormal at that level, but the cross mark should be shifted up or down as little as possible to a more normal portion of the stem.

5. When the tree is forked below breast height, each fork should be treated as though it were a separate tree. If the forking renders the measurements at 4′ 6″ abnormal, the foregoing rule 4 should be applied, the tree counting as one or two according as to whether more acceptable measurements are obtainable above or below 4′ 6″.

6. When buttress formation is characteristic of a species, and is known or is likely to extend upwards with development of the tree, the cross mark should be painted at the lowest level above which abnormal formation is not likely to extend. This height must be standardised for the species, and the relationship between diameter at 4′ 6″ and at this standard height must be separately worked out if required in divisional practice. *See* Plate II.

7. The height above ground level of the cross mark should always be recorded for each tree measured.

(ii) Diameter measurement.

8. When callipers are used, two measurements should be taken at right angles to each other whenever possible. Diameter is then understood to imply the average of the two measurements.

9. Before taking over-bark measurements, climbers, moss, lichen, and loose bark should be removed by hand or with a rough stick. *See* Plate III.

10. Diameter at breast height should be measured at the cross mark on the standing tree.

11. Under-bark measurements should be taken after removing a narrow strip (3″-4″ wide) of bark all round the stem, care being required to ensure that the bark is entirely removed but none of the outer wood with it. *See* Plate IX.

If any objection exists to the removal of such a ring of bark, the necessity may be circumvented by limiting the barking to the points between which the diameters are actually recorded by the callipers, or by callipering all diameters over bark and determining bark thickness separately by the use of a boring instrument such as Pressler's borer.

Photo. R.S. Troup.

Sample Plot 14. West Almora division, United Provinces, in *Pinus longifolia*, Quality II. age 49 years, crop

[illegible] General Rule 9 has not been observed in that the bark has been trimmed off

(*d*) *Standard timber* comprises the volume, *including stump but excluding bark,* down to the limiting diameter of 8″ over bark.

The following treatment of forked trees should be applied.

Any tree forked at a height of less than 4½′ from ground level should be measured as two trees.

For trees forked below the living crown, the larger arm should be treated as the stem, and the volume of the other arm should be recorded separately from the branch wood.

(*e*) *Standard smallwood* comprises the volume, *including bark* between the limiting diameters * of 8″ and 2″ over bark.

(*f*) *Timber and smallwood volumes* of a felled tree should be measured by dividing the total length of each into as nearly as possible equal sections, and by taking the following measurements.

(1) Length of each section.

(2) Under-bark diameter at the middle of each timber section.

(3) Over-bark diameter at the middle of each smallwood section.

The length of the sections should preferably be 10′, odd being feet included in the last section which should not exceed 15.′

Timber and smallwood in branches should be dealt with in the same way when branchwood data are required. Dead branches are not measured.

Standard timber and smallwood volumes of branches, when required, should be measured and recorded separately from those of the stem.

Timber and smallwood sections should be measured straight from end to end, no allowance being made for curvature, hollowness of any other defect, except as additional data when specially called for.

(*g*) Diameter over and under bark at a point half way between breast height and the top of the tree (For *form quotient, see* p. 14).

(*h*) *Ring countings* on the stump, and height of the cut pith above ground level on the uphill side.

(*i*) An estimate of the *quality of locality* on any acceptable standard.

When callipers are in use, fixed iron callipers of 8″ and 2″ diameter may be used with advantage to locate timber and smallwood limits on a felled tree.*

(vii) Commercial measurements.

24. Commercial measurements include the following :—

(*a*) *Diameter over bark* at breast height (Head ii).

(*b*) *Total height* to the nearest whole foot (Head iii).

(*c*) *Commercial timber bole* comprising the length of the stem from the butt as far up as the wood is utilised, or to any limit accepted for the purpose.

(*d*) *Commercial timber* comprising the volume excluding bark from the butt as far up as the wood is utilised, or to any limit accepted for the purpose.

* *N.B.*—The limit of 8″ and 2″ *average* diameter has to be located.

Commercial timber should be measured by dividing the commercial timber bole into as nearly equal sections as possible, and taking on each section the following measurements.

(1) Length of sections. (This should not exceed 20′.)

(2) Under-bark diameter at the middle of the section.

Ordinarily, trees forked below 12′ should not be measured, but when such trees have to be taken, Rule 23 (*d*) for standard measurements should be followed.

(*e*) Diameter over and under-bark at the middle of commercial bole.

(*f*) *Ring counting* on the stump, and the height of the cut pith above ground level on the uphill side(*stump height*).

(*g*) An estimate of the *quality of locality* based on any accepted standard.

CHAPTER III.

Volume Tables.

(i) OBJECTS.

1. To estimate the volume of an average tree of known linear dimensions.

The estimate may be based on diameter and height measurements together, or on diameter alone; in the latter case, some knowledge of quality class of locality may be necessary, and may require height measurement and age determination of selected trees.

2. To estimate the volume of a given crop, or marked trees in it.

This estimate of aggregate volume may similarly be based on diameter and height measurements, or on diameter and quality class data. The figure obtained may be used by a Divisional Forest Officer as a basis for estimates of a marked coupe, or by a Working Plan Officer for the standing volume of a whole Felling Series and hence for calculating stocking and prescribed yield —either an annual average or by prescribed coupes.

(ii) KINDS OF VOLUME TABLES.

Two main types of volume tables require to be differentiated, viz., *general tables* which cover the whole natural range of dimensions for the species, and *local tables*, which are applicable to the more restricted range of dimensions occurring in a given coupe, compartment, or felling series, and can be derived from the general tables. Both kinds of table can be expressed in varying units and may include volume down to any desired diameter limit. For use, it is generally a necessary preliminary to determine whether the tables are applicable to the specific instance, the method being given on p. 25. It is probable that well-defined types within a species will require separate general volume tables.

(A.) *General Volume Tables.*

These tables are compiled for successive diameter classes of convenient range (1", 2" and 4" are most usual), sub-divided into convenient height classes (generally 10′ or 20′) or quality classes (taken from yield tables). The chief use of these tables is for the derivation of local tables as described below.

General volume tables may be compiled in a number of forms as described in the following paragraphs :—

(1) *Standard Volume Tables.*—Here volume is recorded down to the standard limits for timber, 8" over bark at the thin end, with stump included (and likewise for small wood if necessary). These tables are mainly of use as a basis for reference.

(2) *Commercial Volume Tables* (*Outturn in the round*).—The actual diameter limit down to which conversion is done or is customary, is applied instead of the standard limit, stump volume being omitted. The tables are for use only in areas over which the closeness of conversion is the same.

These tables are subject to the limitations that in practice utilisation varies with time (often depending on market conditions) and place. They have much less permanent value than the standard tables, and their chief use is as the basis for the preparation of purely local (and usually temporary) tables for individual coupes, etc. This value will further vary considerably with the stability of local conditions as regards market requirements in kind and amount. Particularly for the lower diameter classes, violent fluctuations are possible which may throw estimates badly out if these classes form a large proportion of the whole. Whether poles (intact or axe trimmed,)

or small sized scantling sawn from small trees are saleable or not, will decide in individual cases between 0 and 100 per cent. utilisation. In such circumstances, it is advisable to estimate separately for the diameter classes concerned. The wastage in conversion may thus be appreciably affected by the nature of the market demands.

(3) *Sawn Outturn Tables.*—The volume of sawn timber actually sawn from trees of different size classes is given. These tables are comparable with (2) above.

(4) *Assortment Tables.*—These give volumes in the round which are included in trees of given height and diameter classes down to various stated thin-end diameters, so that (1) and (2) are really special cases of assortment tables.

(5) *Sawn Outturn Assortment Tables.*—These tables are similar to (4) above, but give sawn outturn in standard sized pieces instead of volume in the round.

(*B.*) *Local Volume Tables.*

From any of the above five forms of tables, simplified tables can be derived (*cf.* p. 32) which are applicable to a restricted locality of more or less uniform quality. Classification by height as well as diameter classes is avoided, as with uniform quality each diameter class will have a fairly uniform average height. This height is estimated from measurements on a restricted number of typical trees. It must be repeated that it may be necessary to demonstrate that the general tables are applicable to the locality in question; *see* p. 25.

In view of the value of local tables for practical application to individual coupes it is inadvisable to attempt to make these tables cover too wide a field. It is better to derive local volume tables for each set of conditions encountered, especially as very little work is needed, given good general tables.

(*C*). *Form Quotient Volume Tables.*

All the above tables, both general and local, can be based on form quotients as well as diameters and heights.

The technique of the use and the methods of preparing form quotient tables has been chiefly developed in Sweden where such tables (Schiffel, Tor Johnson) have been in use for a number of years. These give volumes of trees, classified not only by diameter and height, but also by form quotient classes (Form Classes). Form quotient is defined as the ratio between the diameter at half the height above breast height, and d.b.h., allowance being made for bark-thickness and root swell at the breast height point. Of recent years Form Quotient tables have received considerable attention in America with the result that a number of these have been produced within a short period. In India, Form Quotient tables have not been compiled for any species. The technique, however, is fairly simple, and is outlined below for convenience of reference.

The field work consists in the measurement of total height and of diameter over and under bark at breast height and at 9 points dividing the remaining length into equal tenths. The standard measurements of this code can also be utilized for the purpose, the measurements at the points mentioned being obtained by interpolation, graphic or otherwise. The taper of each tree (diameter measurements against corresponding heights above ground) is then plotted on co-ordinate paper and a smooth curve drawn; values for double bark thickness and butt swell are next obtained and applied to d.b.h. measurement to give the reduced 'true' or 'normal' d.b.h. values. Values of upper diameters as read off the curve are expressed as percentages of the normal d.b.h., giving series of 'percentile tapers,' including the Form Quotient. The percentile tapers are averaged by form classes, an interval of ·050 unit being generally used, and the averages so obtained are plotted, separately for each form class, against lengths from tip to breast height, also expressed as percentages of total height above breast height; smooth curves are then drawn and harmonised. These give '*generalised tapers*' which can be expressed as an equation of the stem form (Hojer's equation is $\frac{d}{D} = C \log \frac{c + l}{c}$ d = diameter at distance l from tip, expressed as percentage of total height above d.b.h. (D); C and c are two constants. In America, another equation (Behre's), $y = \frac{x}{a + bx}$ has been successfully used; y = percentage length from tip, and x = Form Quotient; a and b are constants.

From the generalised tapers are worked out the absolute form factors, which are converted into breast-height form factors, giving values of trees of different heights and diameters classified by form classes.

It is believed that a given set of Form Quotient tables can be applied to a more or less wide group of allied species on the basis of the average Form Quotient for the whole stand. For details, the literature must be consulted.

(*iii*) Compilation of General Standard and Commerical Volume Tables.

(*A.*) *General.*

The following information should be recorded with all volume tables :—

(*a*) Species, common and scientific name.

(*b*) Province, detailed locality, quality class of locality, etc., in which the data have been collected.

(*c*) Units of measurement used, and the portion of the trees measured. (These should whenever possible be the standard ones.)

(*d*) Number of trees measured by d.b.h. and height classes, separately when necessary for each important set of data.

(*e*) Method of computation (preferably standard).

(*f*) Checks applied and results.

(*g*) Relation to other existing volume or yield tables.

(*h*) By whom the measurements were made.

The object of recording these items of information is to make the data available for combination with further data collected on the same lines either previously or in the future. Data collected on the standard procedure and definitions are of the widest application and if for no other reason, are to be preferred.

The 1929 Silvicultural Conference passed the following resolution (No. 12) with regard to the species to which attention should be given in the first place.

" Resolved that Provincial Silviculturists should co-operate in collecting at an early date the necessary data for the compilation of general volume tables for the following species :—

Acacia arabica.
Alnus nepalensis.
Anogeissus latifolia.
Artocarpus Chaplasha.
Bombax malabaricum.
Casuarina equisetifolia.
Cinnamomum Cecidodaphne.
Cedrus Deodara (higher diameters).
Crytpomeria japonica.
Dalbergia latifolia.
Dalbergia Sissoo.
Dipterocarpus pilosus.
Dipterocarpus turbinatus.
Eugenia Jambolana.
Excaecaria Agallocha.
Gmelina arborea.
Lagerstroemia Flos-Reginae.
Mesua ferrea.
Michelia Champaca.
Michelia excelsa.
Populus euphratica.
Pterocarpus Marsupium.
Quercus incana.
Shorea assamica.
Tectona grandis.
Terminalia myriocarpa.
Terminalia tomentosa.
Trewia nudiflora.

Work on other species should, in so far as necessary, be subordinated to these."

(B). Fieldwork.

(a) *Selection of trees.*

(1) Trees of typical height and development should be selected in crops covering the range of distribution to which the results are to be applied. They should be evenly distributed over the range of type or quality class concerned.

(2) Trees with defects other than those which would be regarded as average for crops under study, such as fork, broken top, etc., should not be selected.

(3) Separate sets of trees may be required for different methods of thinning origin of crops, etc.

More discrimination is required in the selection of trees to be measured than has been given to it in the past. A smaller number of trees suitably selected will give better results than a much larger number taken with no selection or with conscious or unconscious selection of trees of one type. Generally, trees above the average tend to be selected. A very common error is to take the trees from too restricted a portion of the area to which it is intended to apply the tables, an error often aggravated by the absence of check or record that the restricted area is in any way typical of the whole.

(b) *Number of trees.*

(4) The number of trees required as a basis for a satisfactory table depends upon :—

(*i*) The grouping adopted.
(*ii*) The precision required.
(*iii*) The deviations of individual tree volumes from the mean in each group.

It should be determined separately for each set of tables. 1,000 trees can be regarded as a satisfactory number, provided that the whole range of diameter and heights is fairly evenly covered, and that the standard deviation is not too high with the grouping adopted.

A method of determining whether an adequate number of trees has been taken is given on p. 4. It must be stressed again that the resultant figure is valueless if the condition is not satisfied that the trees are reasonably representative of the *whole* area concerned. A high degree of accuracy is possible for a small uniform area, but provides no measure whatever of applicability to a larger and more variable area.

Ex. 13. *From the commercial measurements of 9 trees (Pinus excelsa) in one diameter and height class, the volumes were computed ; required the number of trees necessary for measurement so that the volume of the average tree of the class may be accurate within 0·5 c. ft.*

Commerical volumes . = 29·9, 32·8, 26·8, 29·8, 29·3, 29·5, 28·2, 27·3, 30·2 c. ft.

Total . . . . = 263·8.

Average . . = 29·3.

Sum of deviations . . = 11·3.

F_1 *from table for* $n=9$. = ·1477.

S.D. . . = 11·3 × ·1477 = 1·7.

S.E. . . . . = $\frac{0·5}{2}$ = 0·25.

Number of trees required. = $\left(\frac{1·7}{·25}\right)^2 = (6·8)^2$

= 46.

(c) *Measurements.*

(5) For standard volume tables, measurements should be collected as prescribed under General Rule 23 on p. 10. Standard volumes should be recorded whenever possible, even if commercial volumes are primarily required.

The extra work involved in recording standard measurements as well as local commercia volume data is almost always justified, and opportunities of adding in this way to the body of information of general application should not be missed, above all for species concerning which there are few statistical data at present available.

(6) For commercial volume tables, the measurements should be collected as prescribed under General Rule 24, p. 11.

(7) Measurements should be recorded on the standardised form reproduced on the next page.

F. R. I. 139..

Tree volume and outturn.

Species.—*Dalbergia Sissoo.*

Initials.—P. Q. R.

Date.—31-5-30.

Division.—Haldwani.

Block and Compt.—Gaula Block, Comptt. 2.

Quality.—Variable.

Tree No.	2 diameters at breast height (4′—6″). O.b.	U.b.	2 diameters at middle of bole. O.b.	U.b.	2 diameters at thin-end o.b.	Number of rings on stump.	Stump height.
							Ft. Ins.
11	21·0/20·3	19·3/19·0	16·8/15·2	14·1/15·4	12·8/11·0	Unk.	1′—2″
70	26·0/29·9	Unk.	17·5/19·2	15·7/17·5	10·6/11·7	Unk.	1′—8″

Tree No.	Volume of utilisable bole (excluding stump). Length of Section.	Mid-diameter of Section (u.b.). D1.	D2.	Average.	Area of Section.	Volu πr^2.	Outturn in the round. Length of Section.	Mid-diameter of section (u.b.). D1.	D2.	Average.	Area of Section.	Volume πr^2.	Sawn outturn. Dimensions Standard L′×B″×T″	No. of pieces.	Volume per piece.	Total Volume.
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Ft.	Ins.	Ins.	Ins.	Sq. ft.	C. ft.		Ins.	Ins.	Ins.	Sq. ft.	C. ft.			C. ft.	C. ft.
11	12	17·4	18·5	18·0	1·7671	21·2052	12	17·4	18·5	18·0	1·7671	21·2052				
	12	16·2	18·0	17·1	1·5949	19·1388	12	16·2	18·0	17·1	1·5949	19·1388				
	14	11·8	13·4	12·6	·8660	12·1240	14	11·8	13·4	12·6	0·8660	12·1240				
	10	11·8	10·3	11·1	·6721	6·7210	10	11·8	10·3	11·1	0·6721	6·7210				
						59·1890						59·1890	*Nil*	*Nil*	*Nil*	*Nil*
70	18	20·5	20·5	20·5	2·2922	41·2596	18	20·5	20·5	20·5	2·2922	41·2596				
	17	15·7	17·5	16·6	1·5030	25·5510	17	15·7	17·5	16·6	1·5030	25·5510				
	17	10·1	10·8	10·5	0·6014	10·2238	17	10·1	10·8	10·5	0·6014	10·2238				
						77·0344						77·0344				

N.B.—1. Diameters correct to one place of decimals. 2. Sectional area and volume in the round correct to 4 places of decimals. 3. Sawn volume correct to one place of decimals. 4. Lengths of sections recorded to nearest whole foot.

Summary.

Tree No.	Age.	Diameter at breast height.	Total height including stump.	Crown class.	Utilisable bole (excluding stump). Length.	Mid-diameter. O.b.	U.b.	Diameter at thin-end of bole.	Volume of utilisable bole.	Outturn. Round timber.	Sawn timber.	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13
	Yrs.	Ins.	Ft.		Ft.	Ins.	Ins.	Ins.	C. ft.	C. ft.	C. ft.	
11	Unk.	20·7	90	1s	48	16·0	14·8	11·7	59·2	59·2	*Nil*	Rings indistinct.
70	Unk.	28·0	94	1s	52	18·4	16·6	11·2	77·0	77·0	*Nil*	

N.B.—1. Volumes correct to one place of decimals. 2. Only the mean of two diameters recorded. 3. Heights and lengths recorded to nearest whole foot.

(C.) *Computations.*

(a) *The Individual Tree Volume.*

(1) *Sectional area* corresponding to the average mid-diameter of each section should be read from sectional area tables. *See* Appendix VII.

(2) *Volume of each section* should be calculated by multiplying sectional area by length of section correct to four decimal places, or this may be read direct from tables.

Three places of decimals would serve most purposes, but in the long run, it is quicker to use four as all the tables commonly used give four places.

(3) *Timber or smallwood volume* should be obtained to two decimal places by totalling the volumes of the sections measured.

(4) *Derived Units.*—If in addition to π r[2] volumes, volumes in other units are required, they should be derived from the final tables based on π r[2] volumes, *i.e.*, derived unit tables should not be obtained independently from the original individual tree volumes measured in such units.

(b) *Grouping, Averaging and Tabulating.*

(a) *By height and diameter classes.*

(5) The following diameter and height intervals * are convenient as grouping units (groups or classes) :—

Diameter interval	4″.	For trees usually attaining maturity at 20″ d.b.h. & over.
Do.	2″.	For trees usually attaining maturity at 12″—20″ d.b.h.
Do.	1″.	For trees usually attaining maturity under 12″ d.b.h.
Height interval	20′.	For trees usually attaining maturity at a height of 80′ or more.
Do.	10′.	For trees usually attaining maturity below 80′.

(6) All available data are collected by the selected height and diameter classes on the standardised Form 10, an example being reproduced on the next page.

(7) For each diameter-height group, the following diameter-height averages should be computed :—

1. D.b.h.
2. Total height.

* In grouping, it should be remembered that halving the customary limits, say from 4″ to 2″ groups, means that average values for the larger groups do not appear in the tables (*e.g.*, 12″—16″ class, average 14″ ; 12″—14″ and 14″—16″, averages 13″ and 15″),and can only be read from the curves. The greater amount of detail has become a hindrance instead of a help.

VOLUME MEASUREMENT, FORM FACTORS, BARK THICKNESS AND BARK PERCENTAGE OF TYPICAL TREES.

Height Class 61′—80′.
Diameter class 16·1″—20·0″.

SPECIES.—*Pinus longifolia.*

Age.	Height.	Diameter. At 4′ 6″.	Diameter. At half total height. Over-bark.	Diameter. At half total height. Under-bark.	Bark thickness at 4′ 6″.	Bark percentage of total volume.	Solid Volume. Timber. Stem.	Solid Volume. Timber. Branch.	Solid Volume. Smallwood. Stem.	Solid Volume. Smallwood. Branch.	Form Factors. Timber. Stem.	Form Factors. Timber. Branch.	Form Factors. Smallwood. Stem.	Form Factors. Smallwood. Branch.	Length of timber in Stem.	REMARKS.
Year.	Feet.	Inches and decimals.			Inches.		Cubic feet to 2 places of decimals.				To three places of decimals.				Feet.	
87	68	16·5	13·0	10·0	1·70	41	31·66	0	2·30	8·09	·314	0	·023	·080	48	S. P. 14, Rawalpindi Div. (Punjab).
97	69	17·5	Unknown		1·75	Unk.	38·07	0	Unknown		·330	0	Unknown		51	Type Tree, Chakrata Div. (U. P.).
106	72	17·4	„		1·60	„	37·71	0	„		·317	0	„		56	Ditto.
168	66	18·2	12·9	11·4	·95	22	45·79	Unk.	2·94	19·48	·384	Unk.	·025	·163	45	Temp. S. P. III C. Almora Div. (U. P.).
125	69	19·3	12·9	11·2	1·10	25	54·62	„	2·60	3·87	·390	„	·019	·027	50	Temp. S. P. V, Ranikhet Div. (U. P.).
80	80	19·5	14·0	11·6	1·50	31	56·91	0	2·46	2·65	·343	0	·015	·016	64	S. P. 48, Ranikhet Div. (U. P.).
147	80	18·9	14·3	12·3	·95	26	61·98	0	2·15	8·51	·398	0	·014	·055	63	S. P. 71, C. Almora Div. (U. P.)
85	75	16·1	10·8	9·0	1·30	31	33·67	0	3·19	4·39	·318	0	·030	·041	52	S. P. 14, Rawalpindi Div. (Punjab).
120	64	16·5	13·3	12·3	·95	14	39·84	Unk.	1·59	2·67	·419	Unk.	·017	.028	48	Temp. S. P. V, C. Almora Div. (U. P.).
63	78	16·2	11·6	9·4	1·45	34	34·96	„	3·90	0·41	·313	„	·035	·004	55	Temp. S. P. VI, C. Almora Div. (U. P.).
	721	176·1					435·21		21·13	50·07					530	Total.
	(10)	(10)					(10)		(8)	(8)					(10)	No. of trees.
	72	17·6					43·52		2·64	6·26					53	Average.

Sample plot Form 10.

3. Length of bole (standard or commercial).
4. Timber volume (standard or commercial).
5. Smallwood volume (standard only, and only if required).
6. Form factors (any required).
7. Miscellaneous data as required (e.g., thin-end diameter, outturn, conversion factors, etc.).

(7) For each height group (class), average height should be calculated.

(8) The diameter-height averages, together with the number of trees on which they are based, should be recorded on a form such as that reproduced on p. 22. This will be referred to as the "*table of basic averages*" by diameter and height.

(9) When no marked correlation with height has been observed in these compilations under Rule 6 above, or the differences by height classes are relatively small, then further compilation should be made by diameter groups only.

(*B*) *By diameter only.*

(10) The grouping intervals given under Rule 5 above should be used.

(11) Average of the measurements listed under Rule 6 above grouped in each diameter interval (class) should be computed, and tabulated.

(*C*) *By diameters and quality classes.*

(12) The possibility of compiling volume tables by yield table quality classes should be considered.

In dealing with *quality class*, that of the tree should be distinguished from that of the locality. Older volume tables such as those for deodar of the 1919 Kulu Working Plan (*2*), are for tree qualities (actually height diameter classes) only. More recent tables such as those for deodar of 1926 (*3*), take the crop average height and diameter figures from the yield tables, and read the corresponding volumes from the general volume curves, but these figures will again not be found applicable as averages for use in a locality of given average quality owing to the limitations inherent in crop average figures. Hence the procedure given in the following paragraphs is recommended, allotting each locality unit to its average quality class.

(13) For species for which yield tables exist, each unit of area in which measurements are taken should be allotted to its quality, by the ordinary yield table methods.

(14) For species for which yield tables do not exist, average height of trees of determinate ages measured in each unit of area should be plotted against age, and on any suitable basis a series of curves should be drawn delimiting classes.

(15) Data should then be grouped by the quality classes of the area units, and the height/diameter curve on the basis of diameters should be drawn for each quality. The utility of compiling volume tables by qualities should then be decided in view of the divergence of the several curves.

SPECIES.—*Cedrus Deodara.*

Locality—Chakrata, U. P. *Basic averages of volume. Classified by 4" diameter and 20' height classes.*

Height or Quality class.

Diameter class at 4'6".	41'—60'.				61'—80'.				81'—100'.				101'—120'.				121'—140'.				141'—160'.				
	Diameter.	Height.	Volume.	No. of trees.	Diameter.	Height.	Volume.	No. of trees.	Diameter.	Height.	Volume.	No. of trees.	Diameter.	Height.	Volume.	No. of trees.	Diameter.	Height.	Volume	No. of trees.	Diameter.	Height.	Volume.	No. of trees.	Notes
8·1"—12·0"	10·	58	7·5	1	11·6	70	9·5	1	11·8	88	14·2	1													
	11·5	60	6·9	1	10·2	72	8·3	1	10·7	91	13·1	1													
	8·6	60	7·2	1	9·6	64	7·9	1	8·6	86	12·2	1													
	..	..	..	..	..	..	..	..	..	..	..	..													
	..	..	..	..	..	..	..	..	..	..	..	..													
Total .	820·8	4260	580·0	76	2562·2	16038	2247·8	232	304·7	2351	370·2	27													
Average .	10·8	56	7·6	..	11·0	69	9·7	..	11·3	87	13·7	..													
12·1"—16·0"	12·9	44	11·0	1	16·0	79	18·0	1	14·7	89	26·4	1	12·9	104	40·0	1									
	15·7	56	11·9	1	15·2	73	17·5	1	12·8	83	25·0	1	15·7	117	42·1	1									
	14·8	50	11·5	1	13·7	66	16·4	1	15·1	94	27·0	1	14·3	110	41·4	1									
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..									
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..									
Total .	880·0	3648	800·0	65	5250·0	27000	6680·0	380	2840·2	17350	5050·0	198	260·4	1780	725·1	17									
Average .	13·5	56	12·3	..	13·8	71	17·6	..	14·3	88	25·5		15·3	105	42·7										
16·1"—20·0"	17·5	47	18·7	1	16·7	67	28·9	1	16·2	83	39·9	1	17·0	104	50·2	1	19·5	137	79·7	1					
	18·9	54	19·1	1	16·3	63	27·8	1	19·7	98	45·6	1	18·9	110	55·7	1	16·4	131	72·4	1					
	19·7	58	19·9	1	19·4	77	31·0	1	17·2	89	42·4	1	19·6	118	57·4	1	16·9	133	74·5	1					
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..					
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..					
Total .	155·2	535	202·8	9	2330·2	9695	3870·7	133	4099·4	20835	10007·0	229	1343·5	7810	4066·8	73	388·0	2500	1558·0	20					
Average .	17·2	59	22·5		17·5	73	29·1		17·9	91	43·7		18·4	107	55·7		19·4	125	77·7						
20·1"—24·0"					21·4	63	44·3	1																	
					22·8	65	49·7	1																	
					23·3	69	52·8	1																	
					21·1	71	41·9	1																	
					..	..	..	..																	
					..	..	..	..																	
					..	..	..	..																	
Total .					472·6	1693	1082·5	22																	
Average .					21·5	77	49·2																		

(c) *Curves.*

(A) *Smoothing of basic averages by diameter and height.*

(16) Values recorded in the table of basic averages by diameter and height should be smoothed graphically in the three successive steps given below :—

Step 1.—Diameter-height averages of different values (volumes, etc.) should be plotted against corresponding diameter-height averages of d.b.h., separately for each height group (class), using distinctive height group marks such as + * ⊙, etc. The number of measurements forming the basis of each average should be noted against the point.

Smooth curves should be drawn for each height group and then harmonised with reference to one another (*see* p. 6). Values against the middle of each diameter interval should be read from the curves and tabulated.

Step 2.—The average values thus tabulated should next be plotted against average height of each height group separately for each diameter group, using distinctive marks for each group. Smooth curves which will usually approximate to straight lines should be drawn and harmonised.

Values should then be read from the lines or curves against the middle of each height interval.

Step 3.—The values read from the curves in Step 2 should again be plotted against the middle of diameter intervals, and smooth harmonised curves drawn. Final values are read from these curves and tabulated.

(B) *Smoothing averages grouped by diameter intervals only.*—The basic averages to be smoothed should be plotted against corresponding diameter group averages, and a smooth curve drawn ; values are read from the curve against the middle of each diameter interval.

(C) *Smoothing by qualities and diameters.*—The same procedure as in (B) above should be followed for each quality.

(d) *Tables.*

(17) When subordinate tables in units of measurements which are of local or secondary importance are required in addition to tables in standard units which are of wide use or application, the former should always be derived from the latter by the use of the conversion factors. In some cases, a factor can be applied to the whole tables.

Ex. 14.

Principal Table or Curve.	Subordinate Table.	Conversion factors.
1. Standard Volume diameter	Table of πr^2 volume by girths.	Girth/diameter.
2. Ditto	Table of volume by quarter-girth.	Girth/diameter and quarter-girth volume/πr^2 volume.

* In other cases, the conversion factor will vary in the several diameter or diameter-height classes. In such cases, curves and tables for the conversion factor against diameter or diameter-height should be derived, and applied to the table in question.

Ex. 15.

Principal Table or Curve.	Subordinate Table.	Conversion factors.
3. Standard volume/diameter .	Commercial volume/diameter	Calculated percentages of commercial volume to standard volume by diameter classes.
4. Commercial volume/diameter .	Heartwood/diameter . .	Calculated percentages of heartwood in commercial volume by diameter classes.

Ex. 16. *For the heartwood volume for* Acacia Catechu, *the percentage relation to commercial volume varies from 65 per cent. for the 8″—12″ diameter class to 69 per cent. for the 24″—28″ diameter class.*

If trees be assumed to have truly circular section, the conversion factor for girth-diameter is $1/\pi=0{\cdot}31831$, and for (quarter-girth)^2 $/\pi r^2$ volume is $\pi/4=0{\cdot}785$. The average deviation from circular section varies with the species and should be separately determined. A list of the factors which have been determined up to the present will be found on p. 36.

(D) *Checks.*

18. The following checks should be made :—

(*a*) *Aggregate check.*—The actual volume of the trees measured should be checked against the total volume read from the final curves for actual average diameter and interpolated actual average height, both available from the table of basic data.

The difference should not exceed 1 per cent.

Ex. 17. *Data on which the published tables for* Pinus excelsa *are based.*

Standard volume,	Volume obtained by totalling field data.	Volume derived from tables.	Percentage difference.
	C. ft.		
1. Timber	1,27,923	1,28,509	+0·46
2. Smallwood	2,637	2,596	—1·55

The timber is thus well within the prescribed limits ; for the smallwood, a larger variation is permissible and is to be expected ; the agreement found is close enough.

(*b*) *Height/diameter class check.*—This is merely a further analysis of the aggregate check described above, applied to each diameter and height class. The difference between the total volume obtained from the field data and corresponding value read from the curve against actual average diameter and interpolated actual average height, multiplied by the number of trees in the class, should not

differ by more than 5 per cent. At the same time, there should not be less than 20 trees in the class for the check to be reliable.

(c) *Relative check.*—When two or more tables are derived independently from the same data, they should be checked against each other, e.g., volume directly from field data, and volume as the product of cylinders and formfactors.

Ex. 18. *Commercial volume tables for heartwood of* Acacia Catechu.

The procedure recommended is (1) to determine for each height/diameter class (or diameter class only) the percentage relationship between the heartwood volume and commercial volume as recorded in the basic data form; (2) to plot and smooth the percentages so obtained; and (3) to derive the heartwood volume tables from the commercial volume tables. The check would then consist in plotting the basic data for heartwood volume direct, drawing and smoothing the curves as usual, and reading off the mid-class values, and comparing the figures so obtained with those from the procedure first described. Agreement should be within, say, 3 per cent. for each class represented by an adequate number of trees, and if it is not, it should be seen whether the two sets of curves cannot be mutually so adjusted as to reduce the disagreement. The derived curve is the more acceptable in case of disagreement.

Ex. 19. *Local commercial timber volume curve for* Acacia Catechu.

The curve was constructed as described on p. 32, over the general curves for commercial volume data. Values read from the curve should agree within, say, 3 per cent. with the corresponding values read from a curve drawn independently, directly from the basic data, and it will be seen that they do so except for the lowest diameter class which is known to be exceptionally variable.

Diameter class . .	8″—12″	12″—16″	16″—20″	20″—24″	24″—28″	
Volume in c. ft. . .	6·0	14·5	32·0	52·5	76·0	From local volume curve.
	6·3	15·0	31·8	53·0	75·0	From curve drawn direct from basic data.
Percentage difference .	5	3	1	1	1	

(d) *Average deviation check.*—The average deviation of actual individual tree volumes from those read from the curves (with interpolation for height as necessary) may be computed. The utility of this step is explained in the next paragraph. As, however, this check is very laborious, it need only be applied in the case of tables which are considered of importance from the point of view of their possible wide application.

(E) *Applicability of General Volume Tables.*

When volume tables are available for a species, the point which is first to be decided is whether or not these tables are directly applicable in a given locality or to a given coupe. For this purpose a small number of trees, 4—5 in each diameter

height class, should be selected as prescribed under Rules 1—3, p. 24, their measurements (standard or commercial, as the case may be) carefully recorded, and the corresponding volumes read from the curves. The differences of the comparable values of these two series should be averaged (average deviation), and also their algebraic sum determined (aggregate difference).

For the tables to be directly applicable, it is necessary that—

(i) Average deviation (A. D.) of the n test trees should be of the same order of magnitude as that of the basic data of the table. Unfortunately, this has not been recorded for any of the published tables.

(ii) The aggregate difference should not exceed $\frac{2 \times \text{A. D.}}{\sqrt{n}}$.

Ex. 20. *Commercial measurements of 12 trees* (Pinus excelsa) *covering a fairly wide range of diameters were made in a certain area; required to test whether the existing tables are applicable or not. The Average Deviation of the basic data of the tables is taken as 7 per cent.*

The measurements of the test trees, the actual calculated volumes, the corresponding table volumes obtained by interpolation to exact height, and necessary computations are given in the following table :—

Tree No.	D.b.h.	Total height.	Commercial volume C. ft.			Computations.
			Actual.	From the curves.	Difference.	
	Ins.	Ft.				
1	15·1	98	25·8	33·0	7·2	
2	19·6	80	51·0	45·8	5·2	Aggregate difference
3	22·2	93	65·1	70·0	4·9	$=\frac{1852 \cdot 9 - 1772 \cdot 2}{1772 \cdot 2}$
4	23·6	116	111·9	100·4	11·5	=4·6 per cent.
5	24·5	128	130·7	120·0	10·7	Average deviation
6	26·8	112	127·5	123·9	3·6	$=\frac{120 \cdot 1}{1772 \cdot 2} \times 100$
7	27·7	125	165·3	149·1	16·2	=6·8 per cent.
8	27·9	131	191·2	181·1	10·1	Average deviation of basic data=7 per cent.
9	30·4	115	176·3	165·5	10·8	$\frac{2 \times \text{A. D.}}{\sqrt{n}} = \frac{2 \times 7}{\sqrt{12}}$
10	35·4	129	248·3	255·9	7·6	=4·0 per cent.
11	32·4	132	233·5	219·0	14·5	(This quantity, 4·0 per cent., measures the maximum permissible sampling error of the difference of the
12	37·3	140	326·3	308·5	17·8	mean of the Table values and the test trees.)
Total			1852·9	1772·2	120·1	

From the above computation, it would be seen that—

(i) *The average deviation of the trees from the curved values is 6·8 per cent. and so is not appreciably different from that of the basic data (7 per cent.).*

(ii) *Aggregate difference is 4·6 per cent. which only slightly exceeds the quantity* $\frac{2 \times A.D.}{\sqrt{n}}$ *or 4·0 per cent. Hence the existing tables can be directly applied, special tables not being necessary. The small discrepancy may be due to different tree shape, etc., or to a different standard of conversion which may be suspected of influencing mainly the lower diameter classes.*

(iii) *Had the average deviation of the basic data of the general tables been 3 per cent. this sample would shew a significant difference, and the tables could not be applied with confidence that the total volume obtained would agree with that calculated from the tables, within the limits of the sampling error of the difference between the data on which the tables are based and the local test data.*

When the discrepancy is likely to be due to difference in conversion of the smaller diameters, the above test may be applied again after excluding the diameter classes affected, and the latter may be dealt with by a simple percentage correction for the lowest class, if this alone is concerned. Otherwise the new tables required should be derived from the existing general tables by calculating the difference between the actual volume of each test tree and its volume from the tables, and then curving the differences over the corresponding diameters. The smoothed differences are then applied to the general curves and tables.

When the discrepancy is likely to be due to difference in forest type, an entirely new set of tables may be called for, to be compiled exclusively from data collected in the type in question.

(iv) Compilation of General Outturn Tables.

(*A*) *General.*

Figures are required in divisional practice for estimating the actual volumes of timber, etc., likely to be extracted from a given coupe.

When extraction is entirely in the form of logs, the commercial volume tables give the required figure except for the application of a local reduction factor to allow for losses due to rot, hollowness or crookedness, and in cutting the tree into logs of manageable or saleable size. Assortment tables for timber in the round similarly give the volume for any desired thin-end diameter limit.

When the outturn is all in the form of sawn timber, it is preferable to base the estimate on separate tables for sawn outturn volumes, or assortment tables, if available. A great advantage of such estimates is the elimination of the personal element.

When the outturn is partly sawn and partly in the round, it becomes almost impossible to estimate the combined total unless it is known that certain size classes are extracted practically exclusively in the one form or the other, so that they can be dealt with separately.

(B) *Field Work.*

(a) *Selection oft rees.*—Random selection is commonly necessitated by conditions of field work. As a rule, selection is limited to trees measured for standard or commercial volume, and if they are acceptable for the one purpose, they will usually be so for the other, provided no further selection is allowed to occur. When collecting data for outturn independently, the same principles should be followed (as far as conditions allow) as for volume tables.

(b) *Number of trees.*—Sawn outturn will be found to vary considerably for trees of the same height/diameter class and so small numbers of trees are liable to give unreliable results. It should, however, ordinarily suffice for derivation of an outturn table from the commercial volume tables, if not less than 25 trees are measured in each commonly represented height/diameter class.

The number required for a given degree of accuracy will depend on the actual range of variation occurring, and if required, can be checked by the general method given on p. 16, working with the percentage relation to commercial bole volume.

Ex. 21. *The following percentages of sawn outturn to Commercial Volume were calculated from the measurement of 13 trees* (Pinus excelsa) *of one diameter and height class. Required the number of trees in this class for which measurements should be taken to give an accuracy of 0·5 %.*

Total of the percentages .	= 585.
Average percentage . .	= 45.
Sum of deviations . .	= 27.
F_1 *from the table* . .	= ·1004.
S. D.	= 27×·1004.
	= 2·7.
S. E.	$= \frac{\cdot 5}{2} = \cdot 25.$
Number of trees required .	$= \left(\frac{2\cdot 7}{\cdot 25}\right)^2 = (10\cdot 8)^2 = 117.$

(c) *Measurements.*

(1) D.b.h., total height, and total outturn, form the minimum number of measurements required.

(2) The necessary measurements for standard and commercial volumes should also always be recorded when possible.

(3) The outturn should be recorded by numbers of pieces of each size separately.

(4) In recording the size of scantling, etc., standardised sizes should b used in place of actual dimensions, e.g., a B. G. sleeper as 9′×10″×5″, *not* 9′ 6″×11″×5½″.

(C) *Computation.*

(a) Outturn tables should not ordinarily be compiled directly from field data, but indirectly from the tables of commercial volume by means of a table of percentages expressing the relationship between the two for trees of different size classes. The latter table is derived from measurement of an adequate number of trees both ways.

When commercial volume tables do not exist and outturn tables are required with a minimum of delay, the latter may be compiled directly. The procedure for compiling the outturn tables directly from field data is as described for volume tables, but is much simplified by the nature of the data. The same steps should be followed, omitting such as are not required by the data.

(v) Compilation of General Assortment Tables.

(A) *General.*

Assortment tables are made with the following special objects :—

1. To estimate the commercial timber of a coupe in the round, on the basis of the minimum thin-end diameter limit utilised in conversion, and d.b.h. and height, the latter usually being estimated or measured on typical trees.
2. To estimate the sawn outturn of a coupe on the same basis.

The standard timber volume tables take in the whole volume (including stump) down to 8" diameter over bark, whilst the commercial volume tables take in the whole volume (excluding stump) down to a certain limit varying from tree to tree but on the average approximating a definite figure for each size class and decided by the shape of the tree (above all of its crown) and the requirements of the markets. It is quite possible to compute from the standard measurements for the average tree of each height/diameter class, the volume of timber down to any desired thin-end diameter. Tables giving these volumes are termed *assortment tables* and have been compiled for the important European species.

(B) *Field Work.*

(*a*) *Selection of trees.*—As for standard volume tables ; *see* p. 16.
(*b*) *Number of trees.*—As for standard volume tables ; *see* p. 16.
(*c*) *Measurements.*

(1) The minimum thin-end diameter limit down to which the timber is converted for each size of sawn timber should be determined.
(2) Standard measurements should be made.
(3) Measurements for timber down to the fixed thin-end diameter limits should be made, the stump being excluded.
(4) Sawn outturn of each tree should be measured ; standard dimensions should be recorded, but information should also be collected to permit of making the necessary allowance for correction to the average dimensions actually sawn.

(C) *Computations.*

(1) Standard timber and timber up to the fixed thin-end diameter should be calculated, and the latter expressed as a percentage of the former.

(2) The percentages calculated above should be grouped by suitable d.b.h. lasses, and curved over average diameters.

(3) The curved values read from the smooth curve should be applied to the standard volume tables to obtain assortment volumes for different thin-end diameters.

The assortment tables for sawn outturn are developed theoretically from assortment tables for round timber by graphic methods, or by calculation. In the case of the former method, the taper of the typical tree of each diameter class is plotted, and the most economic conversion into sawn sizes assumed (with due allowance for kerf and sawing allowances over the standardised dimensions).

Ex. 22.

Diameter class.	Height class.	Volume in cubic feet.			Bole length in feet.		
		Thin-end diameter.			Thin-end diameter.		
		11″.	13″.	15″.	11″.	13″.	15″.
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
		*94·8	92·1	87·7	88·6	82·0	76·6
	Feet.						
Over 28″—32″ .	121—140	227½	221	210½	103	95	89
	101—120	202	196	187	90	84	78
	81—100	171	166	158½	74	69	64
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
		*91·9	87·4	80·7	85·0	76·9	65·1
	Feet.						
Over 24″—28″ .	121—140	161	153	141	90	82	69
	101—120	143	136	125½	80	72	61
	81—100	122½	116½	107½	65	59	50

Usually these percentages do not show any marked correlation with height making it worth while to group them by diameter/height classes, but if pronounced correlation is noticed, these percentages should be grouped and smoothed both by diameter as well as height.

* *These percentages refer to the corresponding standard volume and bole length and have been applied to the latter to derive the table values.*

Ex. 23. *Sawn outturn for* Pinus longifolia.

Diameter class.	Height class.	Thin-end diameters. 11". 12'×6"×4" Scantlings.	13". 6'×8"×4½" M.G. Sleepers.	15". 9'×10"×5" B.G. Sleepers.	REMARKS.
	Feet.				
Over 28"—32" .	121—140	..	4	23	It is assumed here that conversion is done in the first place for B.G. sleepers, then M.G., and any top piece too thin for a pair of M.G. sleepers, to 6" × 4" scantlings. The table could be prepared on the same lines for any other procedure adopted in the coupes concerned.
	101—120	2	4	16	
Over 24"—28" .	121—140	2	4	17	
	101—120	2	2	14	
	81—100	2	4	9	

In American literature, frequent references will be found to "log rules." A log rule gives an estimate of outturn in *board feet*, i.e., in boards one inch thick, for logs of given length and diameter —the diameter being usually that at the thin-end. Such log rules are based either on graphic considerations, circles of known diameters being divided into rectangles representing the cross-section of the pieces into which logs are converted, or on mathematical considerations, allowance being made for estimated percentage losses in conversion due to saw-kerf, outside slabs, etc.

The accuracy of results obtained with the use of log rules varies with defects in the logs (rot, shake, knots, crookedness, etc.), gauge of saw, intensity of conversion and skill in sawing or conversion.

(*D*) *Application.*

(1) Heights of typical trees in each diameter height class should be measured and curved over diameters.

(2) The actual thin-end diameters down to which timber is converted in the locality in question should be measured for typical trees of all diameters classes, and curved over diameters.

(3) On the basis of the thin-end diameters, d.b.h., and height so measured, outturn in the round or sawn can be read directly from the tables.

(4) It should be remembered that these tables give the theoretically maximum figures, and require a percentage reduction based on actual experience of their application of number of coupes.

(vi) Compilation of Local Volume Tables.

(A) *General.*

Local volume curves and tables should be derived from the general ones for application to individual coupes, etc.

The general object is to eliminate height so that the enumeration or marking lists can be directly converted into volumes, and to have a table for use for the particular average quality class instead of for the middle of the standard quality classes.

The Research staff will usually collect the data for and compile general volume tables whether on the standard or commercial basis, and it will fall to the local staff to derive local curves and tables for local use.

(B) *Field work.*

(1) Each type of locality should be separately dealt with whenever the difference is appreciable.

(2) When compartments have been allotted to quality classes by the working plan, sufficiently close estimates may be obtainable by use of the corresponding curve, but in view of the variation within a quality class, a local curve may still be preferable.

(3) The total height and d.b.h. of four or more typical trees in each 4″ diameter class should be measured, the selected trees conforming with the following specifications :—

(*a*) They should have, as nearly as can be judged, the average height of the trees of their diameter class standing within their immediate vicinity, and

(*b*) They should be as widely and as regularly distributed as possible over the whole area in question.

For measuring height, see Appendix X, p. 253.

(C) *Computation.*

(1) Height and d.b.h. measurements should be averaged for each diameter class and the averages so obtained plotted for a height/diameter curve. If the points do not easily fit a smooth curve, further measurements should be taken if this can be done : if it cannot, the individual heights should be scrutinised for possible abnormalities which can be excluded.

(2) Heights for any convenient diameters such as the middle of the usual 4″ classes, i.e., at 10″, 14″, 18″........should be read from this curve.

(3) These heights should be inte polated between the general volume curves at the corresponding diameters, and a smooth curve drawn through the points.

(4) The volumes corresponding to the middle of diameter classes should be read from this curve and tabulated as the *Local Volume Table.*

Published Volume Tables for Indian species.

Species.	Date.	Locality, etc.	Reference.	Author.
Acacia Catechu . .	1929	North India . .	Ind. For. Rec., Vol. XIII, Pt. IX.	H. G. Champion, I. D. Mahendru and Parma Nand Suri.
Cedrus Deodara . .	1926	United Provinces and Punjab.	Ind. For. Rec., Vol. XII, Pt. VI.	S. H. Howard.
Heritiera Fomes . .	1928	Sunderbans, Bengal	Ind. For. Rec., Vol. XIII, Pt. IV.	Parma Nand Suri.
Pinus longifolia . .	1924	United Provinces, Punjab and Hazara, N.-W. F. Province.	For. Bull. 58 . .	S. H. Howard.
Pinus longifolia . .	1926	Do. .	Ind. For. Rec., Vol. XII, Pt. V.	Do.
Pinus excelsa . . .	1929	Do. .	Ind. For. Rec., Vol. XIII, Pt. VIII.	H. G. Champion, I. D. Mahendru and Parma Nand Suri.
Shorea robusta . .	1922	North India . .	For. Bull. 47 . .	S. H. Howard.
Shorea robusta . .	1924	Do. . .	Ind. For. Rec., Vol. X, Pt. VI.	Do.
Shorea robusta . .	1925	Do. . .	Ind. For. Rec., Vol. XII, Pt. I.	Do.
Shorea robusta . .	1928	Duars, Bengal .	Ind. For. Rec., Vol. XIII, Pt. III.	Parma Nand Suri.
Tectona grandis . .	1922	Tharrawaddy Division, Burma.	Burma For. Bull. 6	H. R. Blanford.
Tectona grandis, Xylia dolabriformis, Terminalia tomentosa, and Dipterocarpus tuberculatus.	1923	Burma . . .	Do. 10	..
Tectona grandis and Shorea robusta.	1925	Central Provinces .	Ind. For. Rec., Vol. XI, Pt. VII.	V. K. Maitland.
Tectona grandis, Heritiera Fomes, Padauk, etc.	1926	Burma . . .	Burma For. Bull. 15	..
Tectona grandis . .	1928	Do. . .	Do. 17	G. S. Shirley.

CHAPTER IV.

Conversion Factors.

(i) CALLIPERED DIAMETER/TAPED GIRTH.

(A) *Objects.*

1. Conversion of girths into the corresponding callipered diameters and *vice versâ.*

2. Conversion of values tabulated by girth classes into the corresponding values tabulated by diameter classes and *vice versâ.*

3. Conversion of quarter-girth volume measurements into πr^2 volume measurements, or *vice versâ.*

Although callipers have widely displaced tapes for measurement of standing trees during the last decade or so, quarter-girth volume is commonly still used, particularly with logs.

These conversion factors are particularly required when data from different sources, some measured one way and some another, have to be combined.

(B) *Procedure.*

(*a*) *Field data.*

(1) Typical trees of all sizes should be selected for measurement.

(2) What is to be considered typical should be decided separately for each locality. Abnormal trees should be omitted altogether, including those with irregularities at breast height.

(3) Two diameters at right angles and the girth should be measured at breast height on each tree.

(4) Trees selected for measurement should be well distributed over the area to which the resulting factor will be applied.

This is very important as it is probable that the conditions under which the trees are growing affect the relationship in question.

(*b*) *Compilation.*

The callipered diameters and girths are averaged by one foot girth classes, and the averages of the former plotted over the latter. A smooth curve, which usually is—or approximates closely to—a straight line, is drawn over the points and should when extrapolated pass through the origin. The ratio of the co-ordinates of any point on this straight line will give the required ratio. If a curvilinear relation is definitely indicated, it means that the ratio varies with size class, and its values must be read off and tabulated by classes.

If the trees were truly circular, the ratio should be $1/\pi = 0{\cdot}3182$, and the deviation from this value will be proportional to the deviation of the average cross section of the tree from a circle; the smaller the factor, the further its shape from a circle.

It must be clearly realised that the factors obtained as described include any errors that may be involved in taking and recording the measurements with the two instruments used: this does not alter their value for practical purposes.

Actual values hitherto recorded are given in the following section on p. 36.

(c) *Number of measurements required.*

For a given species, the number of trees required to be measured for a given degree of accuracy may be determined by the method given on p. 16. The numerical values of the ratios diameter/girth calculated from the data will be the variables in this case.

Ex. 23. *The following diameter/girth ratios were calculated from the measurement of 9 Acacia Catechu trees ; required the number of trees necessary for measurement so that the resulting average ratio may be accurate to the third place of decimals (·0005).*

Diameter/girth ratio .	=·3114, ·3138, ·3107, ·3151, ·3164, ·3094, ·3107, ·3116, ·3094.
Total	=2·8085.
Average . . .	= ·3121.
Sum of deviations .	= ·0184.
F_1 from table . .	= ·1477.
S. D. . . .	= ·0184×·1477=·0027.
S. E.	= $\frac{1}{2}$×·0005=·0003.
Number of trees . .	= $\left(\frac{\cdot 0027}{\cdot 0003}\right)^2$ =81.

(ii) QUARTER-GIRTH VOLUME/πr^2 VOLUME.

(*a*) *Field data.*—No special data are required, as for all practical purposes it suffices to make use of the linear relationship of girth and diameter.

(*b*) *Compilation.*—The required factor f_1 is immediately obtainable from the factor f for conversion of girths into diameters by application of the formula $f_1 = \frac{1}{4\pi f^2}$ which is obtained by combining the equations $d = f \times g$ and $f_1 = \left(\frac{g}{4}\right)^2 \div \frac{\pi d^2}{4}$.

(c) *Recorded factors.*—The factors at present available are as follows :—

Species.	$f = d/g$.	$f_1 = \frac{1}{4\pi f^2}$	Number of trees.
Acacia Catechu	0·3104	0.8259	516
Bombax malabaricum . .	0·3135	0·8097	494
Cedrus Deodara . . .	0·3136	0·8092	*
Dalbergia Sissoo . . .	0·3098	0·8291	*
Heritiera Fomes . . .	0·3111	0·8209	*
Pinus excelsa	0·3133	0·8107	850
Pinus longifolia . .	0·3093	0·8317	*
Quercus incana . .	0·3087	0·8340	*
Shorea robusta	0·3119	0·8181	*

Where the entry for the number of trees is an asterisk,* the precise number has not been placed on record but is believed to be in each case over 500.

The error involved in these figures has not hitherto been calculated, and it is possible that in some cases the difference from true circular section, or as between species, is not significant.

(iii) Solid volume/Stacked volume.

(A) Objects.

1. To convert stacked volume into volume in solid cubic feet.
2. To derive assortment tables for fuel in stacked cubic feet.

(B) Procedure.

(a) Sample stacks.

(1) Sample stacks selected for measurement should be representative of the local practice, as regards size, shape, and quality of billets, as well as of the method and closeness of packing in the stacks.

(2) In the case of the supply of mixed species of woods from a given locality, it should be seen that the mixture of wood species in the stacks is representative of the whole supply.

(3) Hardwoods and softwoods should be stacked and measured separately.

Heavy and light hardwoods or woods with markedly different calorific values are usually differentiated (e.g., oaks from all associates).

(4) Stacks may be made in any convenient size according to local practice, but are preferably of medium size, say not under 100 c.ft. or over 500 c.ft.

(5) Stacks should be of uniform height to obviate any necessity for averaging.

(b) Measurement of stacked contents.

(6) Stacked volume should be determined by measuring length, breadth, and height of the stack correct to the nearest quarter of a foot, but it is preferable that the stacks be built to predetermined dimensions in whole feet.

(c) Measurement of solid contents.

(7) In the case of stacks of round billets, the solid volume of each billet should be determined by the usual measurement of mid-diameter and length of the billet.

(8) In the case of split wood, the solid volume should be determined by weighment. For this purpose, sample billets of regular shape should be obtained, and their weight and volume determined by the usual method; if sample billets of regular shape are not available, the solid volume should be determined by xylometric methods.

Any vessel of uniform section (cylindrical or rectangular) can be used as a xylometer. The volume of the submerged body being equal to the volume of the water displaced, all that is necessary is to note the level of water in the vessel before and after submerging the wood; the cross section of the vessel multiplied by the difference in levels is the solid volume of the submerged wood. Care should be taken not to keep the wood long in the water.

(9) Sample billets should be identical with the splitwood to be measured in all respects, notably as regards the source from which obtained (quality of locality, type of forest growth conditions, portion of the tree utilised). As the billets shrink on drying, care is required that moisture content is similar for all volumes to be compared.

(*d*) *The conversion factor.*

The actual conversion factor is the numerical value of the ratio $\frac{\text{Total volume solid}}{\text{Total volume stacked}}$ and is usually calculated correct to the second place of decimals.

Ex. 24. *Typical conversion factors are recorded as follows :—*

Chir pine . . . . = 0·46 *Ranikhet Division, U. P.*
Oaks . . . . = 0·50 *Ranikhet Cantonment, U. P.*

The results of European investigations with regard to the solid contents of stacked volume are :—

1. The effect of species is limited to the extent of differences in bark thickness, crookedness, and knots, and is generally inappreciable.
2. The straighter, smoother and thicker the pieces, the higher the solid content. For this reason, the smaller the number of pieces, the higher the factor, other things being equal.
3. Tight and parallel packing increase the solid content.
4. Care and skill of labour appreciably affect the solid content.
5. The longer the pieces, the smaller the solid contents of a given volume.
6. In the process of drying, the shrinkage varies with different species ; for a given species it varies with the portion of the tree from which the wood is extracted.

(iv) Weight/Stacked volume.

(*A*) *Objects.*

1. To convert stacked volume into corresponding weight.
2. To derive assortment tables for fuel by weight.

'For weighment of fuel, the usual unit of weight is the maund of 100 lbs. also called a cental'.

(*B*) *Procedure.*

(1) Sample stacks should be selected as for the solid volume/stacked volume factor ; *see* p. 37.

(2) Stacked volume should be determined by measuring length, breadth, and height of the stack as for the solid volume factor ; *see* p. 37.

(3) Stack wood should be weighed on a balance correct to a pound.

Since weather has an appreciable effect on the moisture contents, weighments should not be carried out in moist or bad weather.

(4) The weight recorded will vary greatly according to the time and conditions of storage since the trees were felled. The best procedure in this respect must be determined for each area, depot, or season, and care taken that uniformity is attained in this respect in the determination of each conversion factor.

(5) The required factor is the numerical value of the ratio $\frac{\text{total weight}}{\text{stacked volume c.ft.}}$ correct to a pound.

To each factor should be added specifications of moisture contents of wood, such as "green," "forest dry," "depot-dry" and "air-dry," the terms being explained with reference to the period, place and the conditions of storage.

Ex. 25. *Chir pine 1 c. ft. stacked=23 lbs., Ranikhet Division, U. P.*

CHAPTER V.

Enumerations and Stand Tables.

(i) OBJECTS.

Most enumerations are done to supply the necessary data for assessing the growing stock of a forest with a view to determining the yield. Less frequently they are required for assessing the value for purposes of sale or exchange, and for estimating the returns to be expected from clearfelled coupes. With intensive management of forests in the future, they may also be required for the determination of current periodic increment of crops.

(ii) FIELD EQUIPMENT.

One party engaged on enumerations for research work will require the following instruments, etc.

Callipers . . .	3	Research callipers graduated to tenths of inches. All-metal callipers (such as Fromme's) are best for larger diameters, but metal bound wooden callipers are equally serviceable for small diameters (Flury's, or locally made).
Scribes . . .	2	
Tapes (Linen) . .	2	100′ and 66′.
Steel tape . .	1	25′ long for checking callipers and tapes.
White paint . .	..	Quantity depending on nature of work. Best quality should be used.
Linseed oil . .	..	Quantity depending on nature of work. Best quality should be used.
Forms . . .	..	Perforated books are most convenient.
Chalk . . .	..	....
Hypsometer . .	1	Such as Abney's Level, Model 265 F with stand.

(iii) FIELD WORK.

(A) Size and shape of area to be enumerated.

(1) As large a proportion as possible of the whole area in question should be enumerated.

The whole area should usually be covered in the case of sale or exchange of forest land. The whole of a P. B. I. area should be enumerated for control of yield by volume from uniform system regeneration fellings.

(2) When the whole area cannot be enumerated, at least 10 per cent. should be covered in strips or plots so distributed as to be acceptable as a sample of the standing volume on the forest as whole.

When yield is regulated by volume, it is desirable that the prescribed yield should be based on an acceptable estimate of the volume of the whole forest; and not only a part of it (*e.g.*, the regeneration area only).

(3) Strips are preferable to plots, and should follow lines laid out on a map evenly distributed over the whole area.

Strips a chain wide are most convenient, and parallel strips 10 chains from centre to centre will give a 10 per cent. enumeration.

(4) Plots can be of any convenient shape and size, but they should be numerous and distributed either absolutely at random over the whole area, or in such a way that distinguishable types are represented by areas proportional to their whole extent.

Squares 1 acre in area are most convenient (Side, 206½ feet). If a compartment or other area unit is divided into one acre squares numbered serially, and every 10th square is taken, it will be found that they are often too systematically arranged.

More time is taken laying out squares than lines.

(5) When full enumerations are made, the area should be divided into enumeration units of moderate size to facilitate check and control; record should be kept separately for each control unit, which should not exceed a compartment where compartments exist. An ideal unit is one which can be finished in one day.

Natural features and permanent paths, etc., should be used to divide large areas into smaller enumeration units. The record for each line or plot should similarly be kept separate.

(6) A map showing all enumeration units should invariably accompany the figures.

Enumerations for whatever purpose made should always be copied on to the compartment history where such exists.

(*B*) *Trees to be enumerated.*

(7) In each case, a minimum size limit should be determined down to which enumeration will extend.

It should be remembered that in a normal forest, the relationship between the numbers of successive diameter classes from 20″-24″ downwards closely approximates the summation series, (1) 2, 3, 5, 8, 13........so that every additional class included brings in as many more trees as the last two together. The work involved is not, however, directly proportional to the number of trees particularly in open crops, and the lower diameter limit should always be put as low as practicable.

(8) Trees which are obviously worthless should not be enumerated. Dead and dying trees should be separately recorded.

(9) Trees which fork below 4′ 6″ should be counted as two trees.

(10) Important species should be kept separate, but species of minor importance occurring relatively infrequently need not be distinguished.

Ex. 26. *In one instance, considerable confusion arose because the closely related species* Adina cordifolia *and* Mitragyna parviflora *were enumerated together as the timber of the latter had been reported as suitable for the same purposes as that of the former; purchasers refused to accept the* Mitragyne *and the supplies contracted for could not be completed from the* Adina *available.*

(C) Classes to be distinguished.

(11) Classes to be distinguished should depend upon the object of enumeration.

(12) The customary classes are 1′ girth or 4″ diameter.

Girth classes of 1′ 6″ and even 9″ have been used as the result of successive halving of the common commercially desirable 6′: there is little to recommend this. Diameter classes less than 4″ are sometimes required, particularly for trees not usually reaching large size, and for those in which utilisation is close, *e.g.*, Sandal, *Bruguiera*.

(13) Unless reasons exist to the contrary, standard diameter classes of 4″, 2″ or 1″ should be used.

(D) Rules for callipering.

(14) Before and during work, callipers should be checked to see that they are in proper adjustment.

(15) Trees should be callipered at 4′ 6″ above ground level; in the case of irregularity of stem at 4′ 6″, the point of measurement may be shifted a little up or down (cf. General Rules 1-7, p. 9).

Care should be taken that the point of measurement does not appreciately vary from 4′ 6″ above ground level. For accurate work, a 4½′ stick should be used.

(16) On sloping ground, callipering should be done from the uphill side.

(17) Before callipering, moss and loose bark should be removed.

(18) Callipers should be placed at right angles to the axis of the tree.

(19) Callipers should be read when still in position against the tree.

Before being recorded each call should be repeated by the recorder.

(20) In forests with large heavily buttressed trees, strict application of several of the above rules becomes impossible. They must be modified to a varying extent under such conditions, but it should never be forgotten to record with the figures exactly how the measurements have been taken.

(21) The bark of each tree should be marked with a scribe immediately it is callipered, to obviate any chance of measuring the same tree twice.

In the case of hard barked trees such as *sal*, whitewash is used. Some workers have tried using a distinguishing mark for different diameters or girth classes to facilitate check (*5*, p. 15). It is doubtful if the gain compensates the extra time taken. For illiterate labour, diameter classes may be distinguished by colour (*4*, p. 89).

(E) Field Organisation.

(*a*) *Organisation of parties.*—Each enumeration party should consist of one recorder and two or three callipermen. A couple of linesmen are also necessary at least in the plains.

In most cases, a man carrying drinking water will have to be provided.

If the forest is dense and but little opened up by roads, etc., it may be necessary to arrange for clearing base lines and guide lines ahead of the enumerators, and mapping may be done at the same time.

(*b*) *Organisation of work.*—Callipering should proceed in strips. On sloping ground, the strips should follow contours, but not for too long a distance; the ravines form the best stops. The recorder should follow the calliperman closely, and besides recording the diameters called out by the latter, should see that

callipering is correctly done as regards point of measurement, position of callipers, etc. The width of the strip should be such that the recorder can always see completely across it.

(c) *Additional measurements.*—The advisability of measuring the height of representative trees of each diameter class evenly distributed over the area, should always be considered. These heights give valuable information as to quality of locality if age is known or if the trees are mature, and permit the derivation of local volume tables when general volume tables are available.

(d) *Field Forms.*—A convenient form should be used for the record of enumerations. It is often useful if space is provided in this form for recording the area of the enumeration unit and the date. This will supply data for standardising the output of work under different conditions.

(e) *Rate of work.*—This will vary greatly with local conditions, type of forest, enumeration limits, etc. The range for a party usually lies between 20 and 40 acres (5, p. 13). 300 to 600 trees can be enumerated in a day, the figure going up to 1000 under very favourable conditions.

(F) *Check.*

(22) Enumerations should be checked over not less than 10 per cent. of the area.

(23) The discrepancy between the check and original enumerations should not exceed 3 per cent. in total number of stems, and 5 per cent. in any 4″ diameter or 1′ girth class.

CHAPTER VI.

Tree Increment Plots.

(i) Objects.

Tree increment data are required for the following purposes.

1. Determination of the average time required for typical trees growing under given average conditions to pass through each recognised diameter class. This information is used for determination of rotation and yield.

2. Comparison of increment of trees of different age, diameter and crown class as a guide for suitable treatment.

3. Comparison of the effect of adverse or favourable influences on diameter increment with the object of determining whether sufficient response is made to justify expenditure involved in control or improvement operations.

4. Collection of data for determination of crop increment in irregular forest by what may be termed synthetic methods.

Chapters VII, VIII and IX describe other methods of determining the diameter increment of single trees, *viz.*, Stump Analysis, Stem Analysis and Increment Borings. Of these, the first two involve the death of the tree and so are not applicable when continued observation is needed, though they may be valuable at the end of an investigation.

As compared with increment borings, the tree increment plot has the following advantages :—

1. Field work is decidedly more simple.
2. Field data are more reliable.
3. Check can be made simply and rapidly at any time.
4. Compilation of field data is simpler.
5. Increment is recorded only for a period during which the trees have been under observation, so that any abnormalities in conditions are known.

Viewed in relation to Crop Increment Sample plots, which of course supply the same information (and more) the Tree Increment Plot procedure given here is applicable to :—

1. Uneven-aged crops.
2. Irregularly stocked forest (even or uneven-aged).
3. Mixed forest.
4. Isolated trees.
5. The study of the effect of factors affecting adjoining trees differently, *e.g.*, defoliation.
6. Cases in which data from more trees of a given crown or size class are required than would be available in ordinary sample plots.

(ii) Field Equipment.

Research callipers .	2	All metal (Fromme type), 34" and 24".
Linen measuring tape.	2	100 ft.
Steel measuring tape .	1	12 ft.
Tree scribe . .	1	
Abney's level with stand . . .	1	If required for height measurement.
Plane table with alidade . .	1	If required for mapping.
Khukris . . .	1	
Axes . . .	2	
Experimental Plot Forms 1, 3 and 5 . ..		As required.
Sample Plot Form 3 . ..		As required.

(iii) Field work.

(A) *General Rules for Measurement of Trees.*

The general rules given in Chapter II for measurement of breast height, diameter and height should be followed.

(B) *Special Rules for Measurement of Tree Increment Plots.*

(a) *Selection of Plots.*

(1) Plots should be selected to cover adequately the whole range of quality, type, and geographical distribution to be studied.

(2) Plots should be selected with stocking typical of the forests to which the results obtained are to be applied, both as regards uniformity and density.

(b) *Selection of Trees.*

(3) All the trees in the plot to be kept under observation should be classified in accordance with the object in view into crown classes, wide age classes, defoliation classes, etc.

(4) All the trees in the plot need not necessarily be kept under detailed observation, but only those which are suitable for the object in view.

In most cases, however, it is preferable at least to number all trees of the species under study to avoid a source of possible confusion later.

Ex. 27. *For normal increment in uneven-aged forest, it is a matter for consideration whether only trees likely to reach rotation age or exploitation size should be taken, or a sample of all trees found. What is decided on this point in each case must be clearly recorded, or non-comparable data are liable to be combined later.*

(5) In most cases, it is desirable that each class recognised should be represented by approximately equal numbers, so that results obtained for each, being based on an equal number of observations, are comparable in accuracy.

Ex. 28. *If 5 degrees of defoliation are distinguished : nil, light, moderate, heavy, and complete, it is desirable to have in each class about 1/5 of the total number of trees under observation.*

For increment under conditions typical of uneven-aged forest, data from a single plot are of little value, and all suitable trees should be measured irrespective of relative numbers in each crown or diameter class.

(c) *Shape of Plots.*

(6) Plots may be polygonal or linear in shape; the former should ordinarily be delimited by simple rectilinear boundaries without pronounced re-entrant angles. Linear plots are conveniently one chain or half a chain wide and of any desired length.

(7) A map shewing the outline of the plot and the position of the trees is helpful, and should be prepared when practicable (Plot Chart, Experimental Plot Form No. 5). For linear plots, a field book maintained as for a chain survey serves the same purpose.

Roads, paths and natural boundaries are less objectionable than they are for sample plots, and convenient curvilinear boundaries are also acceptable as exact area is usually not in question.

(d) *Size of Plots.*

(8) Plots may be of any size necessary to include the trees to be kept under observation. Polygonal plots rarely exceed one acre. Linear plots are usually of considerable aggregate area, but records are kept separate for each chain length.

(9) 25 trees should be taken as an absolute minimum in any one plot, and a larger number is desirable.

This rule has it in view to avoid waste of time in visiting a plot for very few measurements.

(10) The sides of a polygonal plot, and the necessary number of diagonals to divide it completely into triangular portions, should be measured by tape to the nearest whole foot. The slope of each line exceeding 10° should also be recorded. The measurements should be recorded on a diagrammatic sketch map inset on the *Situation Map*, Experimental Plot Form No. 1.

Although a knowledge of the area of the plot is usually not essential, it is useful as providing the basis for comparison of density of stocking as between plots.

(e) *Demarcation.*

(11) The corners of a polygonal plot should be marked by means of durable wooden posts serially numbered ; where suitable posts are not available, masonry pillars or cairns should be erected.

(12) Where one post is not visible from the next and the line between them is not perfectly clear, intermediate posts should be erected.

It is not necessary to dig trenches from post to post.

(13) The centre line of a linear plot should be cleared as a path and durable pegs driven in at each chain: the outer edges need not be demarcated.

(14) The number of the plot or line should be indicated on a board or enamelled plate fixed in any convenient and conspicuous portion near the edge of the plot; the year of laying out is a useful addition.

(f) *Numbering.*

(15) All trees to be measured should be cross marked in accordance with general Rules 1-7, p. 9, and serially numbered.

It is often preferable to number all the trees in the plot; cf. note under Rule 4 above.

(16) The numbers should be on the same side of the tree as the cross mark, and are conveniently painted above a line 6″ above the breast height point.

(17) The outer dead bark may be carefully trimmed off with a sharp instrument to give a smooth surface for painting, but great care should be taken that no living tissues are injured or exposed.

(18) On hilly ground, numbering should start from above and should proceed stripwise along contour lines; on level ground, numbering should run in strips parallel to one side of the plot. In linear plots the numbers should run continuously down the line, but rigidity in this respect should be subordinated to convenience.

(19) Where the painted numbers are liable to become indistinct through weathering before they can be renewed, the number should be stamped on a zinc plate to be hung on the nail inserted 12″ above the cross mark in such cases.

(g) *Records.*

(20) The following standard forms should be used for the records :—

Experimental Plot Form	1	Situation Map.
,, ,, ,,	3	Description.
,, ,, ,,	4	Subsequent History.
,, ,, ,,	5	Plot Chart.
Sample Plot Form	3	Diameter measurements. (Includes notes on crown classes or conditions.)

Experimental Plot Form 4 should be used when more convenient than Sample Plot Form 3, as it may be when such factors as defoliation have to be frequently recorded without re-measurement of diameters.

(21) Tree Increment Plots should be numbered exactly like Sample Plots (cf. p. 117), having their own series of numbers from unity for each division.

(22) The following points should be observed in filling in the description of the plot in Experimental Plot Form 3.

1. No entry should be left blank.
2. Great precision is not necessary for the area of the plot, but at least an approximation should be recorded (Entry 4).
3. Situation as regards the forest block and compartment, the Rest House or customary camp from which the plot is inspected, and the road or path by which it is approached, should be noted (Entry 5).
4. Type of forest (Entry 11) should not be confused with condition (Entry 12).

5. Under Initial condition of overwood [Entry 12 (a)] should be recorded notes on the density and uniformity of stocking, appearance as regards quality of boles, general healthiness, etc.

6. Whether the plot is much grazed, fire damaged, etc., should also be noted (Entry 16).

7. Description of the undergrowth should be adequate without becoming profuse. Standard abbreviations (6, p. 92) for frequency should be used, *viz.*, *va*=very abundant, *f*=frequent, *o*=occasional, *r*=rare, *vr.*=very rare. A prefix *l* may be used to indicate that the frequency is local only, but this will rarely be required in these plots. The relative abundance of grass and herbage should be mentioned as well as the shrubs (Entry 12*b* and *c*).

(iv) COMPUTATIONS.

(1) For each set of data, periodic diameter increment and the average diameter should be computed for the mean tree of each diameter class—initial diameter should be used—and the former values curved over the latter.

Instead of current increment, current annual increment per cent may be used if more convenient for the problem in hand.

A comparison of the smoothed increment curves or corresponding points will bring out the influence of the different factors under examination, and therefore in such cases nothing further is required beyond the drawing of the curves.

(2) To determine the average time required by trees to pass through different diameter classes and hence the rotation, the increment curves should be transformed into growth curves based on age. The necessary steps are :—

Step 1.—Starting with the lowest diameter plotted on the increment curve, its increment during the period is read off directly ; this is added to the original diameter to obtain the diameter attained at the end of the period. Increment against this diameter is read off again, and similarly added ; the process is continued for the whole range of values available from the increment curves. Example 33, p. 99, illustrates the method employed.

Step 2.—The diameter values obtained above are plotted against a succession of points equidistant along the horizontal axis, representing the intervals of time corresponding to the number of years in the period.

Step 3.—The time axis of the curve is corrected to read age by shifting the zero point to the left by the necessary number of units equivalent to age to reach the lowest plotted diameter at breast height. This is estimated on any data available.

(3) Crop increment may be determined on the basis of tree increment curves drawn as above, in conjunction with the results of stand and mortality tables.

(*a*) An adequate number of trees of all diameter classes must be included in the plots and measured for this purpose.

(*b*) In the case of linear plots, a stand table is directly derived from enumerations. In the case of polygonal plots, a composite stand table can only be derived by totalling by diameter classes all trees in different plots if the plots have originally been selected with this object.

(c) A mortality table is derived from the records of mortality at successive measurements.

(d) In the case of the irregular forests to which this procedure will usually be applied, dead trees represent a loss which may wholly or partially offset the increment added. In deriving increment in such cases, only the number of trees surviving at the end of the period should be considered for computation.

(e) To determine basal area or volume increment, suitable basal area or volume tables, if available, should be used.

CHAPTER VII.

Stump Analysis.

(i) OBJECTS.

1. To determine the progress of diameter increment on the average stump throughout the life of the trees analysed, or over any desired period.

Usually the results obtained require correction to equivalent rates at breast height before they are suitable for application.

2. To correlate rate of diameter increment with the action of external influences affecting all the trees.

Ex. 29. *The influences may be such as annual burning or weeding, drainage, the density of the crop, treatment applied, and so on. A special case is variation in water table.*

3. To correlate rate of diameter increment with the action of external influences differing from tree to tree.

Ex. 30. *Effect of defoliation by insects, of fungus attack, pruning or resin tapping, all liable to affect each tree to a different extent, some of the factors being controllable and others not.*

4. As compared with the other methods for collecting these data, stump analysis has the following advantages :—

(1) Data can be collected from the stumps of any felled trees as long as the wood remains sound.
(2) Data can be collected at any time and with a minimum of manual labour.
(3) Usually the data can be multiplied to any desired extent with no objection other than the time taken in measuring.
(4) The field work is simple and easily learnt.
(5) Each tree provides data for the whole period of its life.

The method is accordingly particularly applicable to the following investigations :—

(1) Rapid collection of diameter increment data in current or recently worked coupes.
(2) Investigations in which special reasons exist rendering it advisable to have a large number of data, particularly if they are required from all parts of an extensive forest area.
(3) Investigations in areas in which there are objections to the wastage of timber involved in special fellings for collection of data, or in cutting stems at other than the lowest possible level. This will often happen where exceptionally large trees are in question.

(ii) FIELD EQUIPMENT. (For each party.)

Research callipers .	2	All metal, 34" and 24" (Fromme type), marked in inches and tenths.
Tapes (Linen) . .	1	100′
Foot-rules . .	2	One-foot and two-foot, marked in inches and tenths or twentieths.
Pocket lens . .	1	
Abney's level . .	1	
Sharp axe . .	1	
Sharp adze . .	1	A chisel and mallet may be used instead, but are less satisfactory.
Whetstone . .	1	
Stump Analysis Forms	1, 2, 3	As required.
Soft pencils . .	2 or more.	

(iii) FIELD WORK.

(A) Selection of trees.

(1) Ascertain by height measurements of typical mature trees, by ocular inspection or by any other means, whether a significant range of quality class or forest type exists in the area to which the data to be collected will be applied.

(2) It is preferable to deal with each forest type or quality separately, care being taken to cover the whole important range concerned. If it is necessary to deal with all together, each variety must be represented by a number of trees proportional to the total acreage or growing stock of that variety. Locality quality * (or type) and crown class should be recorded whenever possible. The stumps should be well distributed over the forests concerned, and not collected in one restricted area.

(3) Unless impossible, trees should be selected for stump analysis before they are felled.

(4) Trees selected for analysis should be of typical shape and development. What is to be considered typical should be determined with special reference to the growth conditions for which data are required. The common tendency to select trees above the average quality should be guarded against.

(5) The trees should be of rotation size and over. Suppressed or markedly dominated trees should not be analysed but care should be taken that an undue proportion of free-standing trees is not included.

(6) Abnormal trees or trees with any kind of malformation should not be selected, but minor defects such as a little heart rot or fire scarring at the base not greatly affecting the shape of the stump or the course of the rings, need not be taken into account. It is impossible to analyse badly fluted stumps satisfactorily. For cases in which hollowness at the centre of the stump is general, and sound stumps are

* The assessment of quality class will usually involve the measurement of height of 10-20 dominant mature trees (of felled or standing trees distributed over the area.

Photo. H. G. Champion.

Stump analysis of deodar. The decades are marked by pins along two mean radii. The surface is horizontal but not well trimmed. Note the 10" slide rule.

Opposite page :

difficult to find or are open to objection as not typical, a special procedure is described in Section (*F*) below, p. 53.

It is a common practice to pay a minimum of attention to the selection of stumps or trees to be analysed, as regards type and distribution. This has not rarely been intentional on the grounds that a random sample is required, but it has not been realised that it is precisely on this account that the data collected can rarely stand critical scrutiny—the sample very rarely indeed even approaches a random one unless a very large number of stumps is measured up. The extra time and trouble involved in selecting the required type of tree and having them suitably distributed will always be recouped by the significantly greater reliance which can be placed on the resultant data.

(*B*) *Stump height.*

(7) Stumps must be trimmed so that the surface is horizontal. *See* Plate IV.

(8) Stump height for the addition of an allowance for age to grow to that height should be measured vertically from the ground level on the up-hill side to the level of the cut pith of the stump.

(9) Stump height should always be kept as low as practicable, and in any case the range in height should be restricted.

On rare occasions, it is possible to make stump height coincide with breast height, thereby saving labour in collecting taper data, and avoiding any possible inaccuracy involved in their application. The section being also usually more symmetrical, counting and measuring is more quickly effected.

When height growth is sufficiently rapid for the seedling to pass through the whole range of usual stump height in one or two years, Sections (B) and (C) become superfluous. This may be so with teak.

(*C*) *Age to stump height* (*Form 2*).

(10) A number (fifty or more) of free-growing seedlings in the same locality, and with a height range the same as that of stumps to be analysed, should be selected and cut as close to the ground as possible, preferably not more than one inch above it. Their ages should be determined by counting rings, or branch whorls, or by any other method which can be satisfactorily applied for the purpose to the species concerned, the data being recorded on Form 2. With low stumps, differentiation by types or quality classes will not be necessary.

(11) The selected seedlings should be well distributed over the area just as prescribed for the stumps themselves under Rule 2.

In the case of scarcity of suitable seedlings, or uncertainty as to whether such as exist can give the required information as to the time the trees stump-analysed took to reach the recorded stump height, larger saplings may be utilised instead. Their age is determined at ground level and at different heights, say every 6″ through the range of stump heights. The number of years to reach these heights is then obtained by subtraction (cf. Stem Analysis p. 74.)

(*D*) *Taper measurements* (*Form 3*).

(12) On 100 or more marked standing trees *of all sizes* in a coupe to be felled, diameters at right angles to each other should be measured :—

(*a*) Under bark at heights of 6″, 18″ and 30″ above ground level.

It is of course not necessary to girdle the tree at these levels. The bark can be carefully adzed off at 4 points to permit the calliper arms to come into contact with the exposed cambial surface. This procedure would also be followed in the absence of trees marked for felling.

(b) Over bark at 4′ 6″ above ground level (d. b. h.; *see* General Rules 1 to 7, p. 9). Any abnormality at 4′ 6″ should be dealt with as prescribed for standard tree measurements.

(13) The trees measured should be selected in the same way as the stumps themselves, as prescribed under Rules 4-6 above.

(E) *Ring counts and radial measurements* (*Form 1*).

(14) On each stump, two diameters under bark should be callipered at right angles. On badly fluted stumps a second pair of diameters should be callipered between the first.

The customary practice hitherto has been to take the longest diameter and that at right angles to it. There are serious objections to this, of which the chief are that with the low cutting now fortunately fairly general, the stumps are usually widely fluted and the longest diameter is abnormal; and that it is impossible to collect taper data any other way than by callipering (girthing by tape comes to the same thing).

(15) Four radii should be selected for counting such that :—

(a) Growth is typical for the stump.

(b) They are spaced as widely apart as possible. For regularly shaped stumps, they should be at right angles or very nearly so.

(c) They are not appreciably longer than the average radius—*unless balanced by a correspondingly short radius* as will usually happen when 2 radii together forming a diameter are used.

(16) In fairly symmetrical trees, such as most conifers, and in other cases when four suitable radii are not available, two radii (conveniently totalling the mean diameter) approximating closely to the average radius and well apart, will give results of sufficient accuracy. *See* Plate IV.

Use of average radius. It might be thought that considerable labour would be saved by calculating the average radius for the stump, locating one or more radii equal to it on the stump, and counting and measuring them only. This method will give results of acceptable accuracy for regularly grown stumps of even outline such as obtained with most conifers cut with fairly high stumps. As, however, most stump analysis has to be done on fluted irregular shaped stumps cut low, the necessary conditions are not fulfilled, and measurement of a larger number of widely spaced radii becomes essential.

(17) On each radius so marked, rings should be counted in decades from the pith outwards. A pin should be inserted on completing each decade, leaving the incomplete decade on the outer edge of the stump. This number must agree on all radii, discrepancies being checked and corrected.

Number of rings for units of length.—It is possible to make out a case for working with the number of rings in each half inch of radius instead of with the length occupied by 10 rings. The arguments particularly apply to irregular crops where diameter is used as basis for all other measurements and calculations. It has been agreed, however, that whatever inaccuracy may be introduced is outweighed by the convenience of following a standard procedure in all cases. (*7*, p. 183).

The use of pins as described will be found much more convenient, quicker, and more accurate than pencil marks.

(18) Radii should be measured from the pith outwards to each pin. Each measurement should be taken to the nearest ·05 inch.

Errors will be introduced if the stump surface is not plane and horizontal, and if the pins are not inserted vertically and in contact with the scale.

(F) *Field work for hollow stumps.*

It is not at all unusual for the stumps which are to be analysed to have slight rot at the centre, at least sufficient to prevent ring counts right in to the centre ; teak is a case in point. The procedure should then be modified as follows.

(19) The maximum diameter *c* of the hollow or unsound core for which separate data are necessary, should be determined by inspection of a number of stumps. It should always be taken as small as possible.

(20) On the hollow stumps, four suitable radii should be selected, and lines ruled for counting and measurement normal to the rings (with no necessity of meeting at a common central point). A complete annual ring should be so selected * as to have a callipered diameter approximately equal to the diameter *c* above. This ring should be marked out and its mean callipered diameter measured. It is then easy to take a ring one or two outwards or inwards as necessary to give a mean diameter equal to *c*. Analysis then follows, measuring from this ring as though it represented the pith.

(21) A number of trees which are judged to be of the type that has produced those whose stumps are being analysed, should be selected, with diameter equal to or a little greater than the diameter *c* above. These should be felled with the same average stump height, and analysed as prescribed in the foregoing sections. The number should not be less than 25 stumps.

(G) *Record of field data.*

Ex. 31. *A complete but simplified example is given on pp. 58—64 taken from data collected in 1929 for* Cedrus Deodara *in a selection system working circle. As all the steps can be illustrated with ten stumps, only this number has been utilised.*

(*a*) *Stump Analysis Form 1.*—In this form radial measurements for successive decades should be recorded in the appropriate columns, marked 10, 20, 30, at the top. Measurements corresponding to the outermost incomplete decade should *not* be made or recorded. If only two radii are measured and their sum does not equal the average diameter, the outermost measurement should be made and entered *in brackets* in the column for the next higher decade.

This has not been done in Ex. 31 as no space is available owing to the fact that only trees with 100 rings have been utilised here.

Form 1 is so spaced as to take conveniently four radii for each stump, but will obviously serve equally well if only two are taken, together equal to a diameter.

A separate form should be used for each locality quality.

*** A simple device for this consists of two thin strips of wood or metal held together by a central pin so that they can lie one on the other or be opened out at right angles. Each strip is graduated in inches and tenths from the pin outwards.**

(*b*) *Stem Analysis Form 2.*—This is for the record of age and height measurements of seedlings for the determination of the age to stump height, cf. Section (*C*) above.

(*c*) *Stem Analysis Form 3.*—This is for collection of taper data, cf. Section (*D*) above.

(*H*) *Additional measurements recommended.*

When trees have to be felled for stump analysis, the opportunity should not be missed of taking as many as possible of the following useful measurements.

1. *Standard timber volume measurements.*—Or at least diameter under bark at 8″ diameter limit over bark and the length (including stump) to this point.
2. *Commercial timber volume measurements.*—(Diameter under bark at the point up to which commercial utilisation will extend, the length excluding stump to this point, and mid-diameter under bark).
3. *Length of clear bole and length of crown.*—(Length of stem to the first green branch and the lowest point with green branches all round.)
4. *Form Quotient measurement.*—(Diameter under bark at the point midway between breast height and tip.)
5. *Total height.*—(For determination of Quality Class.)

(iv) Computations.

[*See* Example 31 on pages 58 to 64].

(*A*) *Stump diameter/Stump age Curve.*

(1) For each tree, the four radii for each decade should be added and the total divided by two.

If two average radii, or two radii the sum of which equals the average diameter, have been used, the division should obviously be omitted. (Tree 10 of Ex. 31.)

If two radii together not equalling the average diameter have been used, or three radii or four radii not equalling twice the average diameter, the readings should be summed and the total adjusted proportionally to correspond to the average diameter. (This procedure is further explained below, as Section (*E*) and an alternative offered.)

(2) The average diameters so obtained should be brought on to a new form, and totalled and averaged, giving an average diameter for each decade for all the trees analysed. *See* p. 61.

(3) These average stump diameters are then plotted against age and a smooth curve drawn through the points—Curve 1, following p. 64.

(*B*) *Correction from stump age to total age.*

(4) *Construction of the* Stump age/Stump height Curve.—The data collected in Form 2 (p. 65) from seedlings and saplings should be totalled and averaged on the form. The points for average age and average height in each height class should be

plotted and a smooth curve drawn. The curve must obviously start at the origin ——Curve II.

(5) *Determination of age to average stump height.*—Average stump height should be calculated by totalling and averaging Col. 2 of Form 1 (p. 61). The number of years required to reach this height should be read from Curve II—4 years in the example given.

It is often recommended that stump analysis data should be computed separately for two or more stump height classes. With the small range customary in India, the extra labour involved in this procedure is not justified. The error involved in using one stump height class is systematic and of the order of 2 per cent. of the final diameters.

Nothing is gained by allowing for age to stump height on each tree separately, as could be done by counting in from the outermost ring beginning with the number equal to the estimated age. The method prescribed is both simpler and more convenient.

(6) *Adjustment of* Stump diameter/Stump age Curve *to Total age.*—The *Age* scale of Curve I is shifted to the left by a number of units equal to the number of years so determined for age to average stump height, *i.e.*, by 4 in the example.

(*C*) *Conversion of Stump diameters under bark to d. b. h. (over bark).*

(7) The average stump diameter under bark for each height separately should be plotted against the corresponding average d. b. h., the data being directly available from the bottom of Form 3, p. 64. This gives a set of curves—Curve III —one for each height class, which should be harmonised (*see* p. 6).

(8) If the dispersion of these curves is appreciable, an additional curve should be interpolated corresponding to the average stump height (*see* Curve III). But if the curves lie very close to one another, the one which corresponds most nearly to the average stump height of the stumps analysed may be utilised for further computation.

(9) The d. b. h. corresponding to any convenient stump diameters, say 4″, 6″, 8″, 10″........, should be read from the accepted average curve. *See* figures with Curve III.

(10) The points on Curve I.S, for the same series of stump diameters should be shifted to the corresponding d. b. h. figures, and a curve drawn through the new set of points — Curve I.B. — the vertical scale then reading d. b. h. for this curve.

(11) Curve I.-B. for *d. b. h./total age* should then be copied to avoid any possibility of confusion over the scale values, and final values of d. b. h. read off for each decade—these are given on Curve I.

(*D*) *Computation for Hollow Stumps.*

(12) The data for the small trees (Field Rule 21) are worked up exactly as prescribed above, resulting in a curve for stump diameter under bark over the stump age for a range of age from *nil* to the attainment of the diameter *c*.

(13) Curve I is constructed in the same way for the measurements on the hollow trees (Field Rule 20), but will represent the relation between stump diameter (*minus c* inches) and stump age (*minus* age to *c* inches).

(14) The small tree curve is then transferred as an extension of the hollow tree curve, both axes being thereby shifted for the latter. If the curves do not combine smoothly, the adjoining portions should be adjusted, such adjustment being effected as far as possible on the small tree curve.

(15) The rest of the procedure is as usual.

(*E*) *Proportional Adjustment of radial measurements.*

(*Vide* Computation Rule 1 above.)

When the sum of the radii along which measurements are made is not equal to the average diameter or twice it, the measurements have to be corrected proportionally.

(16) *If only a few trees are concerned*, this should be done before they are included in the totals and averages.

Ex. 31. *Tree 9 on Form 1, p. 59, has been corrected in this way.*
Three methods are possible.

Method I.—Each figure is multiplied by a factor equal to the average diameter over the sum of the radii read, *i.e.*, by 14·7 ÷ 17·0 = 0·865 in Tree 9 of Ex. 31.
This method is long and laborious.

Method II.—On squared paper, units are marked off equally on two axes at right angles from zero to the highest double radius concerned, and a point is plotted with co-ordinates equal to the average diameter (y) and the sum of the radii measured (x). This point is joined to the origin, giving a straight line from which the corrected values for all the double radii can be read. This is far quicker than (I), particularly for stumps of the higher ages.

Method III.—Using the slide rule, the value of the average diameter (14·7 for Tree 9) on the moveable scale is set against the sum of the measured radii on the fixed scale (17·0), and the values corresponding to all the double radii can be read directly on the moveable scale by shifting the cursor to each in turn on the fixed scale. Occasionally a second setting may be required, depending on the actual values and the slide rule used. The values can be read almost as fast as the figures can be written down. *See* Plate IV.

The use of the slide rule is very strongly recommended in this connection. Its cost is very reasonable ; its use is very easily mastered ; rapidity in manipulation is quickly acquired, and it saves a great deal of time.

(17) *If a considerable proportion of the trees analysed require such correction*, it is quicker to total the radial measurements for all trees as recorded, divide by the number of radii, and multiply by two to get average diameter as measured. The calculated average radii are dealt with in the same way at the same time, and the final average measured diameter figures for all trees are corrected in one operation proportionately to the ratio : True average diameter/Average diameter used. Provided the radii have been properly selected and the number of trees is not small, this procedure gives all the accuracy required.

(*F*) *Determination of the number of stumps required for analysis, and the accuracy of the average figures obtained.*

The method for determining the number of stumps required for analysis to give a selected degree of accuracy is described on p. 4.

It requires to be stressed that the procedure described presupposes the fulfilment of the conditions set out under "Selection of Trees." It is clear that very consistent results might be obtained by the analysis of stumps in a small exceptionally uniform area, or from a number of stumps all of the same restricted type, but such results would not be of much use for wider application.

Stump Analysis Form No. 1.

Radial Measurements.

Species.—Cedrus Deodara.

Quality.—III.

Division.—Chakrata.

Crown class.—1a.

Block and Compt.—Mundali 2.

Serial No.	Stump height.	Stump diameter under bark.	Radius at successive decade marks. Inches and decimals.									
			10	20	30	40	50	60	70	80	90	100
1	1'-8"	32·0 / 34·6	0·95	3·30	5·00	6·85	8·55	10·05	11·40	12·30	12·90	13·80
			1·30	3·20	5·55	8·10	10·20	12·60	14·25	15·70	16·90	18·15
			1·20	3·30	4·95	6·40	8·10	9·30	10·65	11·25	11·95	13·00
			1·35	3·75	5·80	7·65	9·65	11·70	13·75	15·55	17·50	19·40
			4·80	13·55	21·30	29·00	36·50	43·65	50·05	54·80	59·25	64·35
			2·4	6·8	10·7	14·5	18·3	21·8	25·0	27·4	29·6	32·2
2	0'-5"	10·9 / 11·1	0·20	0·75	1·30	1·65	1·75	2·00	2·20	2·65	3·50	4·70
			0·25	0·65	1·05	1·40	1·50	1·70	1·90	2·20	2·80	3·55
			0·10	0·40	1·50	2·25	2·60	3·00	3·55	4·05	4·85	6·30
			0·15	0·55	1·50	2·30	2·65	3·05	3·70	4·30	5·15	6·40
			0·70	2·35	5·35	7·60	8·50	9·75	11·35	13·20	16·30	20·95
			0·4	1·2	2·7	3·8	4·3	4·9	5·7	6·6	8·2	10·5
3	2'-0"	28·0 / 28·8	1·10	2·80	5·50	8·00	9·80	11·80	13·60	15·90	17·60	19·00
			1·00	2·40	4·25	5·65	6·90	8·00	9·15	10·00	10·85	11·70
			0·80	2·00	3·75	5·10	6·15	7·55	8·30	9·75	10·50	11·10
			1·00	2·40	4·50	6·40	7·95	9·25	10·50	11·75	12·60	13·65
			3·90	9·60	18·00	25·15	30·80	36·60	41·55	47·40	51·55	55·45
			2·0	4·8	9·0	12·6	15·4	18·3	20·8	23·7	25·8	27·7
4	0'-3"	13·9 / 13·4	0·90	2·10	3·20	3·90	4·60	5·15	5·75	6·35	6·75	7·15
			0·85	1·80	2·70	3·35	3·75	4·40	4·95	5·70	6·40	6·80
			0·80	1·75	2·60	2·90	3·40	4·20	4·55	4·85	5·35	5·75
			0·85	2·00	2·95	3·75	4·20	5·00	5·35	5·95	6·60	7·20
			3·40	7·65	11·45	13·90	15·95	18·75	20·60	22·85	25·10	26·90
			1·7	3·8	5·7	7·0	8·0	9·4	10·3	11·4	12·6	13·5
5	0'-3"	15·0 / 14·8	0·50	1·10	1·60	2·30	2·80	3·40	4·45	5·05	5·90	6·95
			[illegible]	1·40	2·05	2·80	3·50	3·95	4·95	5·85	7·30	8·45
			0·65	1·55	2·40	3·20	4·15	4·60	5·60	6·75	7·80	8·40
			0·55	1·20	1·80	2·55	2·90	3·15	3·65	4·05	4·45	5·00
			2·30	5·25	7·85	10·85	13·35	15·10	18·65	21·70	25·45	28·80
			1·2	2·6	3·9	5·4	6·7	7·6	9·3	10·9	12·7	14·4

Stump Analysis Form No. 1.

Radial Measurements.

Species.—Cedrus Deodara.

Quality.—III.

Crown class.—1a.

Division.—Chakrata.

Block and Compt.—Mundali 2.

Serial No.	Stump height.	Stump diameter under bark.	Radius at successive decade marks. Inches and decimals.									
			10	20	30	40	50	60	70	80	90	100
6	0'-7"	19·4 / 19·9	1·00	1·80	3·10	4·45	5·35	6·15	7·15	8·00	8·85	9·70
			1·05	2·25	3·15	4·00	4·90	5·60	6·40	7·40	8·20	9·00
			0·95	1·90	2·75	3·40	4·00	4·70	5·45	6·20	7·70	8·85
			1·15	2·05	3·25	4·35	5·50	6·75	7·65	8·60	9·20	10·65
			4·15	8·00	12·25	16·20	19·75	23·20	26·65	30·20	33·95	38·20
			2·1	4·0	6·1	8·1	9·9	11·6	13·3	15·1	17·0	19·1
7	2'-1"	23·0 / 23·8	0·70	1·75	3·70	5·10	6·75	8·35	9·90	11·80	13·00	14·10
			0·60	1·80	3·45	4·45	5·55	7·25	8·25	9·40	10·50	12·00
			0·70	1·75	3·20	3·90	4·90	5·90	6·80	7·65	8·45	9·30
			0·60	1·50	2·95	3·85	5·05	6·30	6·90	7·85	8·55	9·25
			2·60	6·80	13·30	17·30	22·25	27·80	31·85	36·70	40·50	44·65
			1·3	3·4	6·7	8·7	11·1	13·9	15·9	18·4	20·3	22·3
8	0'-5"	17·9 / 18·2	0·55	1·20	1·60	2·20	2·90	4·20	5·40	5·70	6·60	7·60
			0·50	0·90	1·50	2·20	2·90	3·85	5·20	5·80	7·10	8·00
			0·40	0·90	1·90	2·90	3·90	5·35	6·70	7·50	8·95	9·80
			0·45	1·10	1·90	2·45	3·60	5·15	6·80	7·90	8·90	10·05
			1·90	4·10	6·90	9·75	13·30	18·55	24·10	26·90	31·55	35·45
			1·0	2·1	3·5	4·9	6·7	9·3	12·1	13·5	15·8	17·7
9	1'-9"	14·8 / 14·6	0·35	1·00	1·70	2·45	3·00	3·70	4·30	5·90	6·90	8·20
			0·45	1·30	2·25	2·85	3·70	4·50	5·40	6·70	7·65	8·80
			0·80	2·30	3·95	5·30	6·70	8·20	9·70	12·60	14·55	17·00
			0·7	2·0	3·4	4·6	5·8	7·1	8·4	10·9	12·6	14·7
10	0'-8"	14·2 / 14·6	0·20	0·35	0·70	1·30	2·50	3·10	3·75	3·95	4·25	4·50
			0·40	0·65	1·10	1·90	3·30	5·90	7·15	7·95	9·05	9·90
			0·6	1·0	1·8	3·2	5·8	9·0	10·9	11·9	13·3	14·4

Note.—For tree 9, two radii not equal to the average diameter had to be selected and the measurements have been proportionately adjusted, *vide* Computation Step 16, p. 56. For tree 10, two radii were used which total to the average diameter. In both trees, the number of rings was exactly 100.

Stump Analysis Form No. 1.

RADIAL MEASUREMENTS.*

Species.—Cedrus Deodara.

Quality.—III.

Crown class.—1a.

Division.—Chakrata.

Block and Compt.—Mundali 2.

Serial No.	Stump height.	Stump diameter under bark.	DIAMETER * AT SUCCESSIVE DECADE MARKS. INCHES AND DECIMALS.									
			10	20	30	40	50	60	70	80	90	100
1	20"	..	2·4	6·8	10·7	14·5	18·3	21·8	25·0	27·4	29·6	32·2
2	5"	..	0·4	1·2	2·7	3·8	4·3	4·9	5·7	6·6	8·2	10·5
3	24"	..	2·0	4·8	9·0	12·6	15·4	18·3	20·8	23·7	25·8	27·7
4	3"	..	1·7	3·8	5·7	7·0	8·0	9·4	10·3	11·4	12·6	13·5
5	3"	..	1·2	2·6	3·9	5·4	6·7	7·6	9·3	10·9	12·7	14·4
6	7"	..	2·1	4·0	6·1	8·1	9·9	11·6	13·3	15·1	17·0	19·1
7	25"	..	1·3	3·4	6·7	8·7	11·1	13·9	15·9	18·4	20·3	22·3
8	5"	..	1·0	2·1	3·5	4·9	6·7	9·3	12·1	13·5	15·8	17·7
9	21"	..	0·7	2·0	3·4	4·6	5·8	7·1	8·4	10·9	12·6	14·7
10	8"	..	0·6	1·0	1·8	3·2	5·8	9·0	10·9	11·9	13·3	14·4
TOTAL .	121"	..	13·4	31·7	53·5	72·8	92·0	112·9	131·7	149·8	167·9	186·5
Average .	12"	..	1·3	3·2	5·4	7·3	9·2	11·3	13·2	15·0	10·8	18·7

* For convenience, the same Form is used both for record of the field data and for compilation, and the heading is corrected to refer to diameter instead of radius.

Stump Analysis Form No. 2.

SEEDLING HEIGHT.

Species.—Cedrus Deodara.　　*Division.*—Chakrata.

Quality of locality.—III.　　*Block and Compt.*—Mundali 2.

	HEIGHT CLASS.*															
	1"-6"		7"-12"		13"-18"		19"-24"		25"-30"		31"-36"		37"-42"		43"-48"	
	Age.	Ht.	Age.	Ht.	Age.	Ht.	Age.	Ht.	Age.	Ht.	Age.	Ht.	Age.	Ht.	Age.	Ht.
	1		2	8	5	14	7	19	6	25	9	32	8	38	13	44
	1	3	2	[illegible]	6	16	6	19	10	26	12	34	10	[illegible]	12	43
			4	11	5	16	5	19	8	25	12	36	10	42	14	46
			2	10	3	13	4	19	8	26	14	33	12	40	13	45
			3	11	4	14	9	24	6	27	10	34	..	..	..	..
			2	9	3	14	9	23	9	29	..	..	..	..	..	..
			2	11	3	14	10	22	11	29	..	..	..	..	..	..
			2	10	4	15	7	21	8	30	..	..	..	..	..	..
TOTAL .	2	6	19	78	33	116	57	166	66	217	57	169	40	160	52	178
No. . .	2	2	8	8	8	8	8	8	8	8	5	5	4	4	4	4
Average .	1	3	2	10	4	15	7	21	8	27	11	34	10	40	13	45

* Select 6" or 1' classes to cover the range of stump heights.

Stump Analysis Form No. 3.

TAPER DATA.

Species.—Cedrus Deodara. *Division.*—Chakrata.

Quality of locality.—III. *Block and Compt.*—Mundali 2.

D. B. H. CLASS *4·1"-8·0"*.				D. B. H. CLASS *8·1"-12·0"*.				D. B. H. CLASS *12·1"-16·0"*.				D. B. H. CLASS *16·1"-20·0"*.			
STUMP DIAMETER UNDER BARK.			D.b.h. over bark.	STUMP DIAMETER UNDER BARK.			D.b.h. over bark.	STUMP DIAMETER UNDER BARK.			D.b.h. over bark.	STUMP DIAMETER UNDER BARK.			D.b.h. over bark.
At 6"	At 18"	At 30"		At 6"	At 18"	At 30"		At 6"	At 18"	At 30"		At 6"	At 18"	At 30"	
6·6 / 6·5	6·0 / 5·9	5·6 / 5·4	5·8 / 5·8	10·6 / 10·4	9·6 / 9·8	9·1 / 9·0	9·8 / 9·7	16·5 / 17·1	15·6 / 15·6	15·4 / 15·3	15·8 / 15·7	20·4 / 21·4	20·6 / 20·4	18·1 / 18·5	19·5 / 19·9
4·9 / 4·8	4·5 / 4·4	4·1 / 4·0	4·2 / 4·2	8·9 / 8·8	8·1 / 8·2	7·6 / 7·7	8·1 / 8·3	13·1 / 13·0	12·2 / 12·3	11·5 / 11·5	12·3 / 12·4	17·2 / 16·0	15·5 / 15·3	15·1 / 15·0	16·9 / 15·7
7·1 / 7·0	6·5 / 6·7	6·1 / 6·2	6·6 / 6·4	9·2 / 9·3	8·6 / 8·5	8·0 / 8·0	8·6 / 8·5	14·1 / 13·9	12·9 / 13·1	12·3 / 12·3	13·1 / 13·3	18·1 / 19·4	17·3 / 18·0	17·6 / 17·6	18·1 / 18·4
7·9 / 7·8	7·3 / 7·3	6·7 / 6·9	7·1 / 7·3	9·8 / 9·7	9·1 / 9·2	8·4 / 8·6	9·0 / 9·2	15·6 / 15·4	14·4 / 14·5	13·6 / 13·7	14·7 / 14·5	18·0 / 20·1	16·5 / 18·2	15·5 / 16·4	17·9 / 17·5
8·2 / 8·3	7·5 / 7·4	7·0 / 7·0	7·5 / 7·6	10·9 / 10·7	10·1 / 10·0	9·2 / 9·4	10·3 / 10·1	16·1 / 16·3	15·2 / 15·4	14·3 / 14·4	15·4 / 15·2	20·5 / 24·9	19·2 / 19·7	18·2 / 19·4	19·6 / 18·5
8·6 / 8·8	8·0 / 8·0	7·4 / 7·5	8·0 / 7·9	12·0 / 12·2	11·3 / 11·4	10·6 / 10·4	11·5 / 11·5	16·9 / 16·7	15·8 / 15·6	14·9 / 14·8	16·0 / 15·8	15·3 / 18·3	14·8 / 17·4	14·6 / 16·6	17·5 / 16·0
7·0 / 6·8	6·4 / 6·3	5·8 / 5·9	6·2 / 6·2	12·5 / 12·4	11·6 / 11·8	10·9 / 11·2	11·9 / 11·7	15·0 / 14·8	14·1 / 13·9	13·1 / 13·0	14·1 / 14·0	20·4 / 20·6	19·4 / 19·8	19·3 / 19·1	19·5 / 20·2
100·3	92·2	85·6	90·8	147·4	137·3	128·1	138·0	214·5	200·6	190·1	202·3	270·6	252·1	241·0	255·2
7·2	6·6	6·1	6·5	10·5	9·8	9·2	9·9	15·3	14·3	13·6	14·5	19·3	18·0	17·2	18·2

NOTE.—The data for the 0-4" d.b.h. class are not shown in the above table.

STUMP ANALYSIS CURVES.

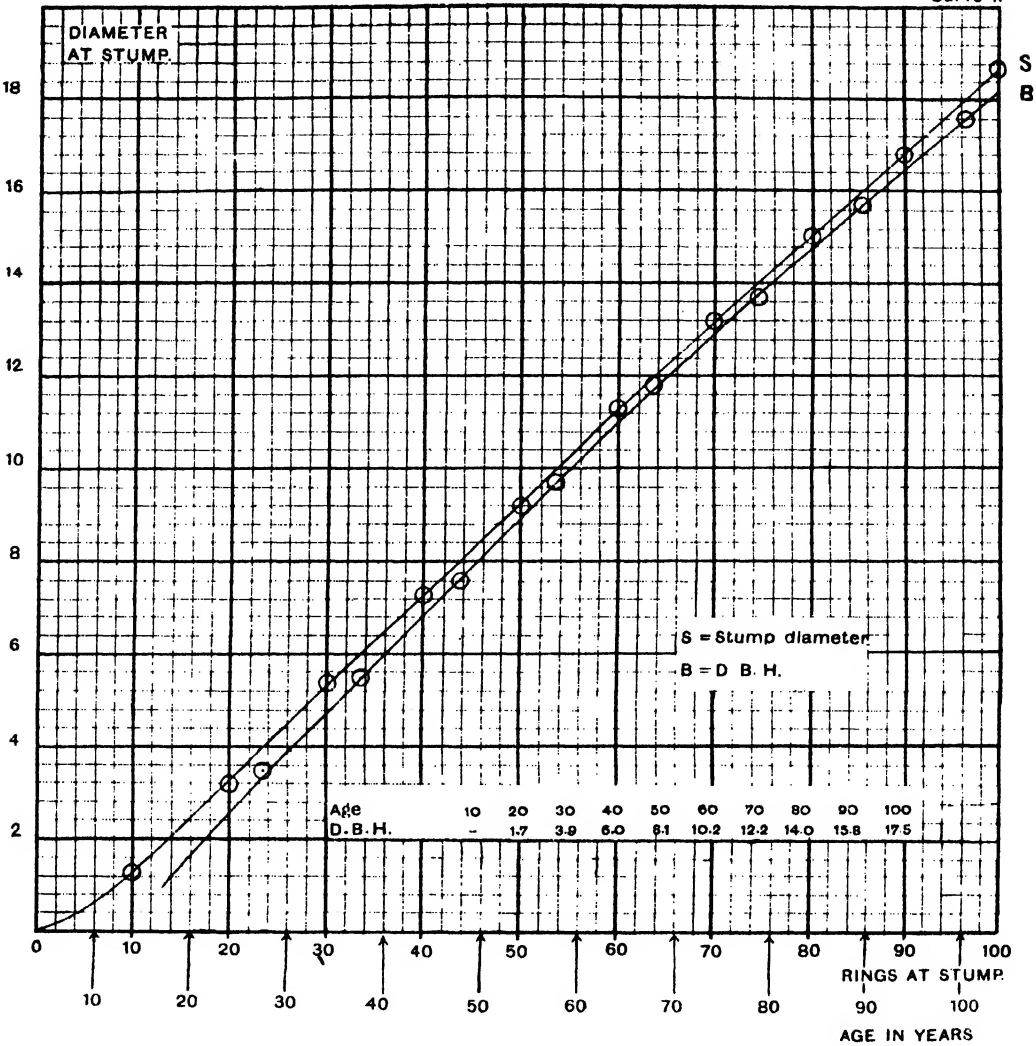
(*The curves occupy pages 67—70.*)

STUMP ANALYSIS.

Species—Cedrus Deodara. Division—Chakrata.

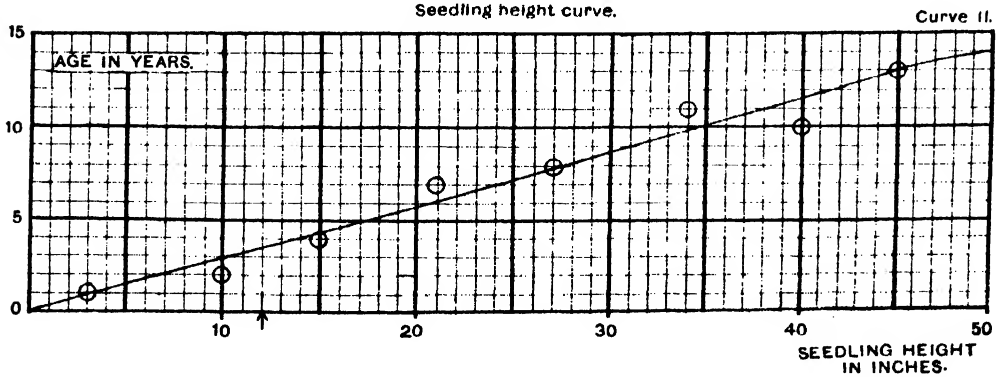
Stump diameter and D. b. h. curves.

Curve I.



Seedling height curve.

Curve II.

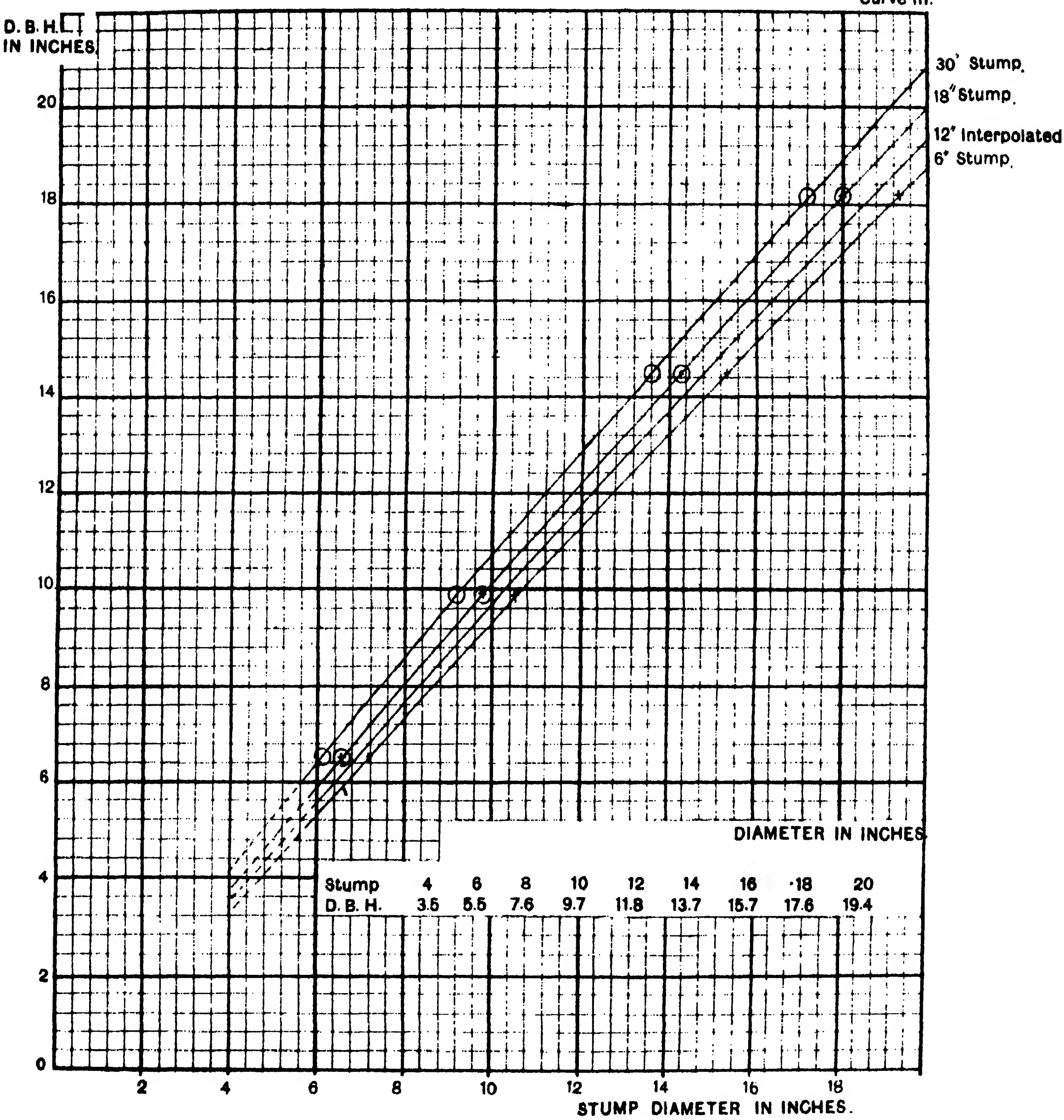


STUMP ANALYSIS.

Species--Cedrus Deodara. Division--Chakrata.

Taper curves.

Curve III.



CHAPTER VIII.

Stem Analysis.

(i) OBJECTS.

1. To determine the average rate of diameter, height and volume increment throughout the life of the trees analysed.

2. To correlate average rate of diameter, height and volume increment with the action of external influences such as defoliation or lopping.

As compared with the other methods for collecting some or all of the same data, stem analysis has the following advantages :—

(*a*) The data are collected from trees carefully selected while still standing as most suitable for the purpose in view, and so are most reliable.

(*b*) The data collected are complete in all respects for the trees analysed, so that no data from other trees or tables are required.

(*c*) The data collected are more reliable than those obtained by any method based only on measurements on the lower part of the bole, since the measurements taken higher up serve as a check on the lower ones.

(*d*) As the sections analysed can be cleaned and examined at leisure, more accurate counting and measurements are possible.

(*e*) The height increment data provide a valuable check on those for diameter increment, for determining whether the trees analysed can be accepted as typical for the purpose in view.

The method is particularly applicable to the following cases :—

(*a*) Estimating volume increment in uneven-aged forest.

(*b*) Following past height increment in sample plots.

(ii) FIELD EQUIPMENT. (For each party.)

(1) Research callipers.	2	All metal, 34″ and 24″ (Fromme type) marked in inches and tenths.
(2) Foot-rules.	2	One-foot and two-foot, marked in inches and tenths or twentieths. A stem analysis rule may replace these.
(3) Measuring tape.	1	100 foot.
(4) Abney's level.	1	
(5) Cross-cut saws.	2	
(6) Hand saw.	1	
(7) Saw set.	1	
(8) Sharpening file.	2	
(9) Tree scribe.	1	(Less satisfactory, one khukri.)
(10) Sharp axes.	2	
(11) Sharp adze.	1	(Less satisfactory, a chisel and a mallet.)
(12) Pins.	100	On a pin cushion.
(13) Soft pencils.	2 or more.	
(14) Stem Analysis Forms 1, 2 and 3	As required.	

(iii) FIELD WORK.

(1) Ascertain by height measurements of typical mature trees, by ocular inspection or any other means, whether a significant range of quality class or forest type exists in the area to which the data to be collected will be applied.

(2) It is preferable to deal with each forest type or quality separately, care being taken to cover the whole important range concerned. If it is necessary to deal with all together, each variety must be represented by a number of trees proportional to the total acreage or growing stock of that variety. Locality quality * (or type) and crown class should be recorded whenever possible; the stems should be well distributed over the forests concerned, not collected in one restricted area.

(3) Trees selected for analysis should be of typical shape and development. What is to be considered typical should be determined with special reference to the growth conditions for which data are required. The common tendency to select trees above the average quality should be guarded against.

(4) The trees should be of rotation size and over. Suppressed or markedly dominated trees should not be analysed, but care should be taken that an undue proportion of free standing trees is not included.

(5) Abnormal trees or trees with any kind of malformation should not be selected, but minor defects such as a little heart rot or fire scarring at the base not greatly affecting the shape of the stump or the course of the rings, need not be taken into account.

(B) *Breast Height.*

(6) D. b. h. should be measured at 4′ 6″ above ground level on the uphill-side in the standard way, before felling.

(7) A horizontal mark should be made at this level all round the bole.

(C) *Stem Sections and Total Height.*

(8) The felled tree should be considered as divided up into sections from the base (including the stump), the lowest section being 9′ long so that breast height corresponds to its mid-point, and the following ones as far as possible (*see* Rule 10 below) all ten feet except the uppermost. The odd length at the top should be treated as a separate section if it exceeds 5′, but included in the previous section if 5′ or less.

(9) The mid-points of the sections are marked on the tree at (4½′, 14′, 24′ ...). The mean diameter over bark is callipered at each mark; a ring of bark is then peeled off, and the under-bark diameters callipered. These measurements are recorded on Form 1, p. 79.

(10) If the mid-points of sections fall on points unsuitable for ring counting on account of knots, rot or breakage, they may be shifted up or down for a distance not exceeding one foot, the sections being treated as though they were actually at the mid-point. If this range does not suffice, the length of the sections affected must be altered to avoid the difficult portion, and the mid-points marked accordingly.

* The assessment of quality class will usually involve the measurement of height of 10—20 mature trees on felled or standing trees distributed over the area.

(11) A transverse sectional disc, 2″-3″ thick, is sawn at each mark for actual ring counting and measurement. When practicable, however, a single cut may be made at each mark, and the measurements taken on the cut ends of the logs.

With very resinous species, it should be remembered that much resin will be exuded on the surface cut first, rendering reading and measurement troublesome, so that it is advisable to cut last the surface it is intended to read. A further advantage is that particularly with unskilled labour, the first cut tends to be oblique, and it is a simple matter to get the second cut made truly perpendicular to the axis.

(12) The length of the successive sections, the height above ground of their mid-points, and the total height are recorded on Form 1 as shown on p. 79.

(D) *Determination of Average Radius.*

(13) For each section, the two under-bark callipered diameters at right angles are totalled and averaged, giving average diameter, and this figure is halved to give average radius.

If diameters are callipered on the disc after removal, whether over-or under-bark, different figures will often be obtained from those measured on the felled tree. Each set of measurements is subject to certain errors, but the procedure prescribed is the more acceptable. If some measurements are taken one way and some the other, serious discrepancies will be introduced.

(E) *Location of Average Radii.*

(14) Two average radii angularly as far apart as possible should be located on each section measuring from the pith to the circumference with the help of the analysis rule or ordinary scale.

(15) If either of these radii is unsuitable from any cause, any other radius selected as normally developed may be substituted. Labour in calculation is then saved if the sum of the two radii used equals twice the average radius, otherwise the measurements must be subsequently adjusted proportionally. *See* Computation Step 3 and p. 56.

(16) The selected radii should be ruled on the section with a soft pencil.

(F) *Ring Counting and Measuring.*

(17) If the annual rings are clear and well spaced, it is only necessary to adze or plane a strip along the selected radii: if they are at all difficult, most or all of the surface of the section must be cleaned. Moistening with water often brings out the rings more clearly. *See* Plate IV.

(18) Rings should first be counted on the section at 4′ 6″. Counting should be done by decades *from the pith outwards* along the lines marked. A pin should be inserted on completing each decade, leaving the incomplete decade at the circumference, and it should be checked that there is the same number of rings on each radius.

(19) On each of the remaining sections, a number of rings corresponding to the outermost incomplete decade on the 4′ 6″ section should be marked off first, *counting from the cambium.* This is 6 rings for Ex. 32.

(20) The remaining rings should be marked off in decades counting inwards, and the total number noted (Form 1, Col. 4, p. 79).

(21) Radii should be measured to each pin beginning with the outermost. These measurements should be taken to the nearest ·05 inch.

(G) *Bark Thickness.*

(22) The difference between the over-bark diameter and the under-bark diameter measured before cutting the sections is twice the bark thickness.

(H) *Additional Measurements.*

(23) The following additional measurements can usefully be taken and recorded :—

- (*a*) The length of the stem including stump, to the point at which the diameter over bark is 8″. (For standard timber volume of tree.)
- (*b*) The length of the stem to the first green branch and lowest point with green crown on all sides. (Clear bole and crown length.)
- (*c*) The diameter over and under bark at the point mid-way between breast height and tip. (Form quotient measurement.)
- (*d*) The length of the stem up to a diameter limit of 2″ diameter over bark. (Standard stem smallwood.)
- (*e*) The length excluding stump and defective butt to any point or points on the stem which may be of importance from the point of view of utilisation of timber. (Commercial bole length.)
- (*f*) Under-bark diameters at the mid-points of convenient sections of this commercial bole, each section not exceeding 30′. (Commercial volume in the round.)

(J) *Age to Breast Height* (*Form 2*).

(24) A number (50 or more) of free growing seedlings from 3′ to 6′ in height should be selected, and their ages determined by any method which can be satisfactorily applied for the purpose to the species concerned ; the data should be recorded in Form 2, p. 84.

(25) It is preferable to deal with each forest type or quality separately, care being taken to cover the whole important range concerned. If it is necessary to deal with all together, each variety must be represented by a number of trees proportional to the total acreage or growing stock of that variety. Locality quality (or type) and crown class should be recorded whenever possible, and the stems should be well distributed over the forests concerned, not collected in one restricted area.

(26) If suitable seedlings are not available, the required data can be collected from small saplings of somewhat greater height by ring countings at ground level and at heights of $3\frac{1}{2}$, $4\frac{1}{2}$ and $5\frac{1}{2}$ feet.

(K) *Record of Field Data.*

Ex. 32. *A simplified example is given on p. 79, taken from data collected in 1929 for* Picea Morinda. *As all the steps can be illustrated with five stems, only this number has been utilised.*

(*a*) *Stem Analysis Form 1.*

(i) The radial measurements for the outermost full decade along the two selected radii on the lowest section (at $4\frac{1}{2}'$) are entered under the appropriate decade heading in the columns provided for them, heading 80 in Ex. 32, Tree 1.

(ii) Successive radial measurements on this section are then entered in continuation across the form to the right.

(iii) Measurements on the remaining sections are successively recorded in order, the first entry for each being made under the first entry for the first section, i.e., in the column headed 80 for tree No. 1 of Ex. 32, p. 79.

(iv) Measurements against the outside incomplete decade should *not* be made or recorded unless the sum of the radii used is not equal to twice the average radius; in this case they should be entered in brackets in the column for the next higher decade.

(*b*) *Form 2.*

This form provides for the collection of data for the age of seedlings up to breast height; the same form as used for Stump Analysis, but the height classes adopted are ordinarily different—3′-4′, 4′-5′, and 5′-6′ are most suitable. *See* Example on p. 84.

(iv) COMPUTATIONS.

[*See* Example 32 on pages 79 to 94.]

(A) *Calculations for each tree* (*Form 1*).

(1) The number of years taken to grow from breast height to the heights of successive sections should be determined by subtracting the number of rings on the section from the number of rings at 4′ 6″. This number should be filled in in Col. 3.

(2) The diameters over bark and under bark at 4′ 6″ should be averaged, and double bark thickness at each section should be calculated by subtraction and entered in Col. 7.

(3) The measurements for the two radii should be totalled on Form 1 to the nearest first place of decimals.

If two radii together not equalling the average diameter have been used, the readings should be summed and the total adjusted proportionally to correspond to the average diameter. (This procedure is further explained in a note on p. 56.)

(B) *Calculations for all trees together.*

(a) Height Curve.

(4) The figures for age above breast height to reach given sectional heights in Cols. 3 and 2 of Form 1 should be classified and averaged (Form 3). The averages are plotted and a smooth curve drawn, Curve I.

The majority of the sections will fall at the standard heights of $4\frac{1}{2}'$, $14'$, $24'$ .... but in the upper parts of the trees deviations will be frequent. Entries on Form 3 should be kept to the left of the column, and any deviations entered to the right. The deviations should be totalled algebraically and divided by the *total* number of entries (not by the number of deviations). Before plotting, the standard height will be corrected by the quotient so obtained. Examples occur for heights 104, 114, and 124.

Before totalling, the figures should be scrutinised, and any tree which appears abnormal or exceptionally slow-grown should be excluded. As a rule, only trees attaining the age up to which the final results are desired should be included.

In drawing the curve, the fact may be borne in mind that with this method of construction, there is a systematic tendency towards lower values for height at a given age.

(b) Diameter Curves by decades.

(5) The diameters under bark at different heights should be collected from all trees, separately for each decade, on a series of copies of Form 3, totalled and averaged. *See* pp. 88—90.

(6) The average values are plotted against corresponding height of sections separately for each decade, and the curves smoothed and harmonised. (*See* p. 6.) Curves II -IV are thus obtained.

This is done in 3 steps :--

Step 1.—Average diameter are curved over heights of sections and smoothed. Values are read against $4\frac{1}{2}'$, $14'$, $24'$ heights. Curve II.

Step 2.—The curved values obtained above are plotted against decades separately for each section, and smooth curves drawn. Curve III.

Step 3.—The values read off from the last curve are again replotted, and smooth curves drawn. Curve IV.

If the average height deviates from the standard at the head of the column, it will be known from the data in the previous section (*a*).

In harmonising, the higher decades should be given most weight. The curves should agree with the height curve constructed under (*a*) above, and mutual adjustments should be made as far as possible.

(c) Volume Curves by decades.

(7) For each decade, the volume of the mean tree is obtained by calculating and totalling the volumes of its constituent sections, lengths and mid-diameters of which are directly available from the curves drawn under (*a*). *See* pp. 92, 93.

For the first entry, 0·0917 is the sectional area corresponding to a diameter of 4·1″, and the length being 9′, the volume is 0·8253. The top log is taken as a cone, *see* the third section for decade 10 on p. 92.

(8) The tree volumes are then plotted against age above breast height and a smooth curve drawn. Curve V.

(d) D. b. h. curve.

(9) Average d. b. h. under bark by decades can be read directly from the $4\frac{1}{2}'$ curve of the set drawn under (*b*) above. Double bark thickness at breast height is taken from tables if available; if tables are not available, the data from all sections are averaged by 4″ *d. b. h.* under-bark classes, and a curve drawn for double bark thickness against d. b. h. under-bark. *See* Curve VI. From this curve the required data can be read for correcting each of the diameters under bark to standard d. b. h. This correction is made, and d. b. h. is curved over age above 4′ 6″—Curve VIII.

(e) Correction from breast-height age to total age.

(10) The data collected in Form 2, p. 84 from seedlings and saplings should be totalled and averaged on the form. The points for average age and height in each height class should be plotted and a smooth curve drawn. The curve must obviously start at the origin—Curve VII.

(11) An average figure for age to breast height is read from this curve—14 years—and the zero point of age for the three curves obtained under (*a*)—(*c*) is shifted to the left by the necessary number of units so that height, d. b. h. and volume can be read off against decades of total age.

(f) Final correction to be applied to volume growth figures.

The figures of growth in volume obtained by the above method are derived from the mean tree for each decade of age on the basis of diameters. The values obtained are consistently low as compared with figures obtained by the more usual method, according to which volumes are first calculated separately for each decade for each tree, and these volumes then averaged for all trees. A correction (which ordinarily amounts to about 3%) can be applied to the figures of volume obtained by the first method to correspond approximately with the figures obtained by the second, on the assumption that values of mean trees obtained by the two methods vary directly as their basal area. In the average case, it is not necessary to make this correction.

If D is the average of a number of d. b. h. measurements, d_1, d_2, d_3, etc., and σ the standard deviation, the basal area of the tree of average basal area is

$$= \frac{\pi}{4}\,\frac{\Sigma\,(D \pm \sigma)^2}{n} = \frac{\pi}{4}\,\frac{nD^2 + n\sigma^2 \pm \Sigma\,2D\sigma}{n} = \frac{\pi}{4}\,(D^2 + \sigma^2).$$

The volume of the mean tree of *average diameter* is $\frac{\pi}{4}\,D^2$.

The ratio of the basal area and hence the volumes of the two mean trees by the two methods is therefore $\frac{D^2 + \sigma^2}{D^2}$ or the relative error (percentage) $100 \times \frac{\sigma^2}{D^2}$.

(g) Growth in volume to any given diameter limit over bark.

From the bark thickness data, the diameter under bark corresponding to the given limit over bark is determined. From the curves under (*a*) above, the height at which this under-bark diameter limit is reached, can be read for each decade

of age, and the mid-diameter of length of each 9′ or 10′ section below it. The volume of these sections has already been calculated under (c), and it only remains to add in the volume of the incomplete section.

Assuming that the taper is constant between the given diameter limit and the next point below which has been measured, the diameter at the top end of the last complete section is obtained by proportion. The mean of this diameter and the given limit (both under bark) gives the mid-diameter of the incomplete section; its length is known, and so its volume can be calculated and added in.

This is done for each decade, and a smooth curve drawn over the points from which the required values are read.

Stem Analysis Form No. 1.

Species.—Picea Morinda.
Quality.—I.
Crown class.—1*a*.

RADIAL MEASUREMENTS.

Division.—Chakrata.
Block & Compt.—Kanasar, 23.

Tree No. 1.

Serial No. of Section.	Height of section.	Age to section.	Rings on section.	Diameter. Over-bark.	Diameter. Under-bark.	Twice bark thickness.	Average radius under bark.	Length of section.	Radius at successive decade marks. Inches and decimals. 100	90	80	70	60	50	40	30	20	10	Additional measurements.
	Ft.	Yrs.	No.	Ins.	Ins.	Ins.	Ins.	Ft.											
1	4½	0	86	20·6 20·6 20·6	19·2 19·2 19·2	1·4	9·60	9			9·20 9·25 18·5	8·15 8·15 16·3	7·50 7·15 14·7	6·20 6·40 12·6	5·35 5·80 11·2	4·65 5·00 9·7	3·65 4·00 7·7	2·10 2·15 4·3	Total height 105'. Height to first green branch 54'. Height to full crown 60'.
*2	14	4	82	18·1 18·1 18·1	17·5 16·9 17·2	0·9	8·60	10			8·30 8·30 16·6	7·55 7·65 15·2	6·80 6·95 13·8	5·75 6·05 11·8	4·95 5·20 10·2	4·20 4·45 8·7	3·10 3·25 6·4	1·25 1·20 2·5	
3	24	11	75	17·4 17·4 17·4	16·6 16·5 16·6	0·8	8·30	10			8·00 8·10 16·1	7·20 7·50 14·7	6·35 6·70 13·1	5·30 5·80 11·1	4·25 4·85 9·1	3·25 3·85 7·1	1·90 2·15 4·1		
4	34	17	69	16·7 16·7 16·7	16·1 15·7 15·9	0·8	7·95	10			7·70 7·60 15·3	7·00 6·95 14·0	6·20 6·10 12·3	5·00 4·75 9·8	3·75 3·10 6·9	2·20 1·90 4·1	0·50 0·60 1·1		
5	44	26	60	15·1 15·4 15·4	14·6 14·2 14·4	1·0	7·20	10			6·85 6·95 13·8	6·00 6·10 12·1	5·00 5·10 10·1	3·70 3·70 7·4	2·35 2·40 4·8	0·60 0·65 1·3			Average clear bole 57'. Average crown length 48'.
6	54	35	51	14·3 14·3 14·3	13·5 13·1 13·3	1·0	6·65	10			6·10 6·20 12·3	5·15 5·25 10·4	4·00 4·05 8·1	2·50 2·55 5·1	0·85 0·85 1·7				
7	64	43	43	12·0 12·0 12·0	11·3 11·1 11·2	0·8	5·60	10			5·15 4·85 10·0	4·00 3·85 7·9	2·60 2·60 5·2	0·95 0·95 1·9					
8	74	53	33	10·2 10·2 10·2	9·6 9·0 9·3	0·9	4·65	10			4·00 4·00 8·0	2·80 2·80 5·6	1·15 1·20 2·4						
9	84	63	23	7·4 7·4 7·4	6·7 6·5 6·6	0·8	3·30	10			2·80 2·65 5·5	1·30 1·25 2·6							Height to 8" D.o.b. 83'. D.u.b. at 8" o.b 7·3"/7·3. Height to 2" d.o.b. 101'. D.u.b. at 2" o.b. Unk.
10	94	70	16	4·4 4·4 4·4	3·6 3·6 3·6	0·8	1·80	10			1·15 1·25 2·4								
11	102	78	8	1·8 1·8 1·8	1·3 1·3 1·3	0·5	0·65	6			0·15 0·15 0·3								
																			*Length of stem small wood 18'. Height from b.h. half way to top 50·3'. D. u. b. at this point 13·8/13·8.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Stem Analysis Form No. 1.

Species.—Picea Morinda.

Quality.—I. **RADIAL MEASUREMENTS.** *Division.*—Chakrata.

Grown class.—1*a*. *Block & Compt.*—Kanasar, 23.

Tree No. 2.

Serial No. of Section.	Height of section.	Age to section.	Rings on section.	Diameter. Over-bark.	Diameter. Under-bark.	Twice bark thickness.	Average radius under-bark.	Length of section.	Radius at successive decade marks. Inches and decimals. 100	90	80	70	60	50	40	30	20	10
	Ft.	Yrs.	No.	Ins.	Ins.	Ins.	Ins.	Ft.										
1	4½	0	100	26·0 26·6 26·3	25·7 24·9 25·3	1·0	12·65	9	12·15 12·05 24·2	11·50 11·20 22·7	11·00 10·75 21·8	9·90 10·15 20·1	8·80 9·20 18·0	7·80 8·35 16·2	6·80 7·30 14·1	5·50 5·90 11·4	4·00 4·10 8·1	2·40 2·00 4·4
2	14	7	102	23·0 24·1 23·6	22·8 21·6 22·2	1·4	11·10	10	10·80 10·70 21·5	10·40 10·00 20·4	10·00 9·50 19·5	9·50 8·90 18·4	8·60 7·90 16·5	7·90 7·10 15·0	7·00 6·15 13·2	5·70 4·80 10·5	3·60 3·15 6·8	1·00 1·00 2·0
3	[illegible]	12	97	22·0 22·1 22·1	21·4 20·8 21·1	1·0	10·55	10	10·20 10·50 20·7	9·70 9·80 19·5	9·30 9·25 18·6	8·75 8·70 17·5	7·85 7·95 15·8	7·05 7·20 14·3	6·00 6·20 12·2	4·40 4·90 9·3	2·20 2·70 4·9	
4	34	16	93	21·1 20·8 21·0	19·8 19·9 19·9	1·1	9·95	10	9·60 9·65 19·3	9·10 9·10 18·2	8·65 8·70 17·4	8·10 8·20 16·3	7·10 7·30 14·4	6·40 6·50 12·9	5·25 5·20 10·5	3·70 3·60 7·3	1·25 1·20 2·5	
5	44	20	89	19·5 19·7 19·6	18·7 18·6 18·7	0·9	9·35	10	8·90 9·10 18·0	8·50 8·60 17·1	7·95 8·10 16·1	7·30 7·50 14·8	6·40 6·65 13·1	5·60 5·75 11·4	4·30 4·50 8·8	2·55 2·65 5·2		
6	54	25	84	18·2 18·6 18·4	17·0 17·4 17·2	1·2	8·60	10	8·35 8·20 16·6	7·80 7·65 15·5	7·40 7·20 14·6	6·70 6·60 13·3	5·80 5·65 11·5	4·90 4·75 9·7	3·40 3·30 6·7	1·25 1·25 2·5		
7	64	30	79	16·8 17·0 16·9	15·6 16·1 15·9	1·0	7·95	10	7·60 7·50 15·1	7·10 6·90 14·0	6·55 6·40 13·0	6·00 5·80 11·8	5·10 4·75 9·9	4·00 3·80 7·8	2·40 2·25 4·7			
8	74	34	75	16·6 15·4 16·0	14·8 13·9 14·4	1·6	7·20	10	6·80 6·70 13·5	6·20 6·10 12·3	5·65 5·50 11·2	4·95 4·80 9·8	3·95 3·90 7·9	2·80 2·75 5·6	0·95 1·00 2·0			
9	84	41	68	13·4 14·3 13·9	12·5 13·4 13·0	0·9	6·50	10	6·00 6·10 12·1	5·40 5·55 11·0	4·80 4·95 9·8	4·00 4·20 8·2	2·80 3·20 6·0	1·50 1·90 3·4				
10	94	47	62	11·7 11·4 11·6	10·8 10·1 10·5	1·1	5·25	10	4·80 4·80 9·6	4·10 4·30 8·4	3·50 3·80 7·3	2·75 2·95 5·7	1·75 1·75 3·5	0·50 0·40 1·0				
11	104	57	52	8·3 8·0 8·2	7·3 7·4 7·4	0·8	3·70	10	3·30 3·10 6·4	2·70 2·45 5·2	2·10 1·90 4·0	1·35 1·30 2·7	0·25 0·25 0·5					
12	114	70	39	5·9 6·4 6·2	5·6 4·9 5·3	0·9	2·65	10	2·10 1·90 4·0	1·50 1·40 2·9	1·05 1·00 2·1							
13	125½	95	14	2·4 2·6 2·5	2·2 1·8 2·0	0·5	1·0	13	·5 ·5 1·0									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Additional Measurements. (20)

Total height 132'.
Height to first green branch 43'.
Height to full crown 89'.

Average clear bole 66'.
Average crown length 66'.

Height to 8" D.o.b. 105'.
D.u.b. at 8" o.b. $\frac{7·2}{7·2}$.
Height to 2" d.o.b. 126'.
D.u.b. at 2" o.b. $\frac{1·6}{1·5}$.

Length of stem small wood 21'.
Height from b.h. half way to top 63·8.
D. u.b. at this point $\frac{14·0}{15·2}$.

Stem Analysis Form No. 1.

Species.—Picea Morinda.

Quality.—I.

Crown class.—1a.

RADIAL MEASUREMENTS.

Division.—Chakrata.

Block & Compt.—Kanasar, 23.

Tree No. 3.

Serial No. of section.	Height of section.	Age to section.	Rings on section.	Diameter. Over-bark.	Diameter. Under-bark.	Twice bark thickness.	Average radius under-bark.	Length of section.	Radius at successive decade marks. Inches and decimals. 100	90	80	70	60	50	40	30	20	10	Additional measurements.
	Ft.	Yrs.	No.	Ins.	Ins.	Ins.	Ins.	Ft.											
1	4½	0	99	28·0 26·3 27·2	26·9 25·2 26·1	1·1	13·05	9		12·90 12·80 25·7	11·70 11·60 23·3	10·65 10·65 21·3	9·70 9·40 19·1	8·30 8·15 16·5	7·15 6·85 14·0	5·65 5·10 10·8	3·65 3·35 7·0	1·70 1·70 3·4	
2	14	5	94	23·8 24·0 23·9	23·0 22·7 22·9	1·0	11·45	10		10·90 10·90 21·8	10·00 9·95 20·0	9·25 9·10 18·4	8·50 8·25 16·8	7·25 7·20 14·5	6·05 6·20 12·3	4·60 4·90 9·5	2·80 3·20 6·0	·80 ·90 1·7	
3	24	11	88	24·4 22·4 23·4	21·2 22·1 21·7	1·7	10·85	10		10·30 10·30 20·6	9·35 9·50 18·9	8·50 8·80 17·3	7·80 7·95 15·8	6·70 6·85 13·6	5·70 5·70 11·4	4·20 4·10 8·3	2·25 2·20 4·5		
4	34	15	84	22·1 21·6 21·9	21·5 20·2 20·9	1·0	10·45	10		9·80 9·95 19·8	8·80 9·15 18·0	7·90 8·40 16·3	7·15 7·60 14·8	6·00 6·25 12·3	4·85 5·00 9·9	3·30 3·30 6·6	1·15 1·15 2·3		
5	44	19	80	20·4 20·4 20·4	18·9 20·0 19·5	0·9	9·75	10		9·15 9·15 18·3	8·20 8·35 16·6	7·25 7·60 14·9	6·40 6·60 13·0	5·30 5·45 10·8	4·10 4·15 8·3	2·25 2·20 4·5	·15 ·20 ·4		
6	54	25	74	19·3 19·3 19·3	18·8 17·9 18·4	0·9	9·20	10		8·50 8·60 17·1	7·15 7·80 15·0	6·80 6·95 13·8	5·85 5·95 11·8	4·65 4·60 9·3	3·30 3·30 6·6	1·30 1·35 2·7			
7	64	30	69	17·0 17·4 17·2	16·8 16·1 16·5	0·7	8·25	10		7·55 7·60 15·2	6·45 6·60 13·1	5·55 5·70 11·3	4·50 4·65 9·2	3·20 3·20 6·4	1·80 1·85 3·7				
8	74	35	64	15·3 15·5 15·4	14·3 14·2 14·3	1·1	7·15	10		6·50 6·45 13·0	5·70 5·50 11·2	4·80 4·65 9·5	3·65 3·50 7·2	2·30 2·10 4·4	·85 ·70 1·6				
9	84	44	55	12·9 12·7 12·8	12·0 11·7 11·9	0·9	5·95	10		5·45 5·20 10·7	4·60 4·15 8·8	3·80 3·30 7·1	2·60 2·20 4·8	·90 ·90 1·8					
10	94	51	48	10·4 10·1 10·3	9·1 9·3 9·2	1·1	4·60	10		4·00 4·00 8·0	2·95 3·20 6·2	2·10 2·40 4·5	1·15 1·35 2·5						
11	104	60	39	6·8 6·9 6·6	5·8 5·3 5·6	1·0	2·80	10		2·20 2·20 4·4	1·00 1·45 2·5	·85 ·80 1·7							
12	113	80	10	2·0 2·0 2·0	1·5 1·5 1·5	0·5	0·75	8		·40 ·40 ·8									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	

Additional measurements:

Total height 117'.
Height to first green branch 63'.
Height to full crown 66'.
Average clear bole 65'.
Average crown length 52'.
Height to 8" D.o.b. 102'.
D. u. b. at 8" o. b. $\frac{7·4}{7·3}$
Height to 2" d. o. b. 113'.
D. u. b. at 2" o. b. $\frac{1·9}{1·9}$
Length of Stem small wood 11'.
Height from b. h. half way to top 56·3'.
D. u. b. at this point [illegible]

Stem Analysis Form No. 1.

Species.—Picea Morinda.

Quality.—I.

Crown class.—1*a*.

RADIAL MEASUREMENTS.

Division.—Chakrata.

Block & Compt.—Kanasar, 23.

Tree No. 4.

Serial No. of section.	Height of section.	Age to section.	Rings on section.	Diameter. Over-bark.	Diameter. Under-bark.	Twice bark thickness.	Average radius under-bark.	Length of section.	Radius at successive decade marks. Inches and decimals. 100	90	80	70	60	50	40	30	20	10
	Ft.	Yrs.	No.	Ins.	Ins.	Ins.	Ins.	Ft.										
1	4½	0	109	27·5 27·0 27·3	26·7 25·7 26·2	1·1	13·10	9	12·70 12·85 25·6	12·30 12·30 24·6	11·85 11·85 23·7	11·30 11·30 22·6	10·40 10·40 20·8	9·30 9·20 18·5	7·95 8·00 16·0	6·45 6·40 12·9	4·40 4·30 8·7	1·85 1·70 3·6
2	14	8	101	24·5 24·5 24·5	23·0 23·1 23·1	1·4	11·55	10	11·25 11·20 22·5	10·60 10·50 21·1	10·20 10·10 20·3	9·65 9·70 19·4	8·80 9·20 18·0	7·85 8·30 16·2	6·65 7·10 13·8	5·15 5·40 10·6	2·90 3·05 6·0	0·40 0·40 0·8
3	24	13	96	22·7 22·4 22·6	21·5 20·3 20·9	1·7	10·45	10	10·30 10·25 20·6	9·80 9·65 19·5	9·40 9·20 18·6	8·00 8·65 17·6	8·15 7·80 16·0	7·30 6·85 14·2	5·90 5·70 11·6	4·20 4·25 8·5	1·80 1·60 3·4	
4	34	18	91	21·0 21·4 21·2	20·6 19·9 20·3	0·9	10·15	10	9·70 9·90 19·6	9·39 9·45 18·8	8·80 9·00 17·8	8·25 8·45 16·7	7·40 7·65 15·1	6·50 6·60 13·1	5·00 4·95 10·0	3·10 3·10 6·2	0·35 0·35 0·7	
5	44	22	87	19·4 19·9 19·7	18·5 17·7 18·1	1·6	9·05	10	8·85 8·80 17·7	8·40 8·20 16·6	7·95 7·75 15·7	7·50 7·10 14·6	6·70 6·70 13·4	5·60 5·25 10·9	3·95 3·80 7·8	1·85 1·85 3·7		
6	54	27	82	17·9 17·7 17·8	17·0 16·4 16·7	1·1	8·35	10	8·05 8·10 16·2	7·50 7·60 15·1	7·05 7·10 14·2	6·40 6·45 12·9	5·50 5·45 11·0	4·20 4·20 8·4	2·55 2·65 5·2	0·55 0·50 1·1		
7	64	33	76	15·4 15·6 15·5	15·3 14·1 14·7	0·8	7·35	10	7·10 7·05 14·2	6·40 6·40 12·8	5·90 5·80 11·7	5·05 4·80 9·9	4·00 3·70 7·7	2·70 2·50 5·2	1·20 1·10 2·3			
8	74	43	66	13·6 13·2 13·4	12·2 11·9 12·1	1·3	6·05	10	5·60 5·70 11·3	4·85 5·15 10·0	4·20 4·65 8·9	3·30 3·75 7·1	2·20 2·60 4·8	1·05 1·25 2·3				
9	84	51	58	10·9 10·8 10·9	9·9 9·7 9·8	1·1	4·90	10	4·40 4·50 8·9	3·70 3·75 7·5	3·00 3·00 6·0	2·15 2·00 4·2	1·00 0·90 1·9					
10	94	64	45	7·2 7·1 7·2	6·2 6·0 6·1	1·1	3·05	10	2·55 2·70 5·3	1·80 2·20 4·0	1·20 1·60 2·8	0·55 0·80 1·4						
11	105½	85	24	2·2 2·1 2·2	1·6 1·7 1·7	0·5	0·85	13	0·35 0·35 0·7									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19

Additional measurements. (20)

Total height 112'.
Height to first green branch 56'.
Height to full crown 68'.

Average clear bole 61'.
Average crown length 51'.

Height to 8" D. o. b. 92'.
D. u. b. at 8" o. b. $\frac{7\cdot2}{6\cdot8}$.
Height to 2" d. o. b. 107'.
D. u. b. at 2" o. b. $\frac{1\cdot7}{1\cdot8}$.

Length of stem small wood 15'.
Height from b. h. half way to top 58·8'.
Diameter u. b. at this point unk.

Stem Analysis Form No. 1.

Species.—Picea Morinda.

Quality.—I.

Crown class.—1*a*.

RADIAL MEASUREMENTS.

Division.—Chakrata.

Block & Compt.— Kanasar, 23.

Tree No. 5.

Serial No. of section.	Height of section.	Age to section.	Rings on section.	Diameter. Over-bark.	Diameter. Under-bark.	Twice bark thickness.	Average radius under-bark.	Length of section.	Radius at successive decade marks. Inches and decimals. 100	90	80	70	60	50	40	30	20	10	Additional measurements.
	Ft.	Yrs.	No.	Ins.	Ins.	Ins.	Ins.	Ft.											
1	4½	0	98	28·8 30·6 29·7	27·3 29·8 28·6	1·1	14·30	9		13·55 13·80 27·4	12·45 13·00 25·5	11·65 12·10 23·8	10·55 11·15 21·7	9·30 9·95 19·3	8·20 8·65 16·9	6·95 7·05 14·0	5·05 5·10 10·2	2·15 2·60 4·8	
2	14	6	92	24·7 23·4 24·1	23·5 21·7 22·6	1·5	11·30	10		10·90 10·80 21·7	10·20 10·10 20·3	9·50 9·50 19·0	8·75 8·70 17·5	7·80 7·80 15·6	6·80 6·80 13·6	5·50 5·55 11·1	3·75 3·80 7·6	1·25 1·30 2·6	
3	24	9	89	22·9 22·3 22·6	21·3 21·3 21·3	1·3	10·65	10		10·25 10·30 20·6	9·60 9·80 19·4	9·00 9·30 18·3	8·30 8·60 16·9	7·50 7·75 15·3	6·50 6·80 13·3	5·10 5·20 10·3	3·20 3·15 6·4	0·45 0·50 1·0	
4	34	13	85	21·6 21·4 21·5	20·0 19·9 20·0	1·5	10·00	10		9·55 9·70 19·3	8·90 9·00 17·9	8·25 8·35 16·6	7·50 7·60 15·1	6·50 6·55 13·1	5·50 5·30 10·8	4·10 3·80 7·9	2·10 1·95 4·1		
5	44	16	82	21·2 20·2 20·7	19.5 18·7 19·1	1·6	9·55	10		9·10 9·20 18·3	8·35 8·55 16·9	7·60 7·80 15·4	6·75 6·00 13·7	5·85 5·80 11·7	4·55 4·30 8·9	3·00 2·80 5·8	1·0 0·90 1·9		
6	54	20	78	20·5 18·9 19·7	18·2 17·4 17·8	1·9	8 90	10		8·50 8·55 17·1	7·90 7·80 15·7	7·20 6·95 14·2	6·25 5·85 12·1	5·00 4·60 9·6	3·60 3·20 6·8	1·40 1·35 2·8			
7	64	30	68	17·0 17·8 17·4	15·6 16·6 16·1	1·3	8·05	10		7·50 7·60 15·1	6·60 0·80 13·4	5·96 5·95 11·9	4·80 4·65 9·5	3·50 3·35 6·9	2·00 1·90 3·9				
8	74	35	63	15·0 15·2 15·1	14·2 13·7 14·0	1·1	7·00	10		6·50 0·10 12·9	5·60 5·40 11·0	4·80 4·45 9·3	3·75 3·45 7·2	2·40 2·20 4·6	1·00 0·90 1·9				
9	84	46	52	12·2 12·7 12·5	11·5 11·4 11·5	1·0	5·75	10		5·20 5·05 10·3	4·20 3·95 8·2	3·15 3·00 6·2	1·90 1·75 3·7	0·55 0·60 1·2					
10	94	56	42	9·7 10·0 9·9	9·0 8·5 8·8	1·1	4·40	10		3·80 3·70 7·5	2·80 2·75 5·6	1·90 1·80 3·7	0·60 0·50 1·1						
11	104	70	28	6·1 6·1 6·1	5·3 5·3 5·3	0·8	2·65	10		2·00 2·15 4·2	1·10 1·15 2·3								
12	114	80	18	3·8 3·8 3·8	3·1 3·1 3·1	0·7	1·55	10		1·00 1·00 2·0									
18	122½	91	7	1·1 1·1 1·1	0·8 0·8 0·8	0·3	0·40	7		0·4 0·4 0·8									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Additional measurements:

Total height 128'.
Height to first green branch 62'.
Height to full crown 73'.
Average clear bole 68'.
Average crown length 58'.
Height to 8" D. o. b. 99'.
D. u. b. at 8" o. b. $\frac{6\cdot9}{6\cdot9}$.
Height to 2" d. o. b. 120'.
D. u. b. at 2" o. b. $\frac{1\cdot5}{1\cdot6}$.
Length of stem small wood 21'.
Height from b. h. half way to top 60·8'.
D. u. b. at this point $\frac{15\cdot0}{15\cdot2}$.

Stump Analysis Form No. 2.

Seedling Height.

Species.—Picea Morinda. *Division.*—Chakrata.

Quality of Locality.—I. *Block & Compt.*—Kanasar, 23.

	Height Class*							
	37"—48"		49"—60"		61"—72"		73"—84"	
	Height	Age	Height	Age	Height	Age	Height	Age
	42	12	54	14	66	16	78	17
	42	9	54	11	66	12	78	13
	42	16	54	23	66	28	78	30
	42	8	54	10	66	11	78	11
	42	10	54	12	66	13	78	14
	45	10	53	12	64	13	77	14
	39	12	51	16	63	18	75	19
	40	13	58	17	61	16		
	39	12	49	14				
	38	11	55	15				
	43	12	49	15				
	42	14	51	16				
	45	15						
Total .	541	154	636	175	518	127	542	118
No. .	13	13	12	12	8	8	7	7
Av. .	42	11·9	53	14·6	65	15·9	77	16·9

* Select 6" or 1' classes to cover the range of stump heights.

Note.—The form used is primarily intended for Stump Analysis, *vide* p. 62.

Stem Analysis Form No. 3.

HEIGHT COMPUTATION.

Species.—Piceà Morinda.

Quality.—I.

Crown c'ass.—1*a*.

Division.—Chakrata.

Block & Compt.—Kanasar, 23.

Tree No.	Height of Section (Feet).																									
	4½		14		24		34		44		54		64		74		84		94		104		114		124	
		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.		Dev.
1			4		11		17		26		35		43		53		63		70		78	−2				
2			7		12		16		20		25		30		34		41		47		57		70		95	+1½
3			5		11		15		19		25		30		35		44		51		60		80	−1		
4			8		13		18		22		27		33		43		51		64		85	+1½				
5			6		9		13		16		20		30		35		46		56		70		80		91	−1½
Total			30		56		79		103		132		166		200		245		288		350	−½	230	−1	186	0
No. .			5		5		5		5		5		5		5		5		5		5	5	3	3	2	2
Av. .			6		11		16		21		26		33		40		49		58		70	−·1	77	−·3	93	0

Stem Analysis Form No. 3.

Mean diameter Computation for decades (10—40).

Species.—Picea Morinda. *Division.*—Chakrata.

Quality.—I. *Block & Compt.*—Kanasar, 23.

Crown class.—1*a*.

	Height of Section (Feet).																									
Tree No.	4½	Dev.	14	Dev.	24	Dev.	34	Dev.	44	Dev.	54	Dev.	64	Dev.	74	Dev.	84	Dev.	94	Dev.	104	Dev.	114	Dev.	124	Dev.
Decade 10.																										
1	4·3		2·5																							
2	4·4		2·0																							
3	3·4		1·7																							
4	3·6		0·8																							
5	4·8		2·6		1·0																					
Total	20·5		9·6		1·0																					
No. .	5		5		1																					
Av. .	4·1		1·9		1·0																					
Decade 20.																										
1	7·7		6·4		4·1		1·1																			
2	8·1		6·8		4·9		2·5																			
3	7·0		6·0		4·5		2·3		0·4																	
4	8·7		6·0		3·4		0·7																			
5	10·2		7·6		6·4		4·1		1·9																	
Total	41·7		32·8		23·3		10·7		2·3																	
No. .	5		5		5		5		2																	
Av. .	8·3		6·6		4·7		2·1		1·2																	
Decade 30.																										
1	9·7		8·7		7·1		4·1		1·3																	
2	11·4		10·5		9·3		7·3		5·2		2·5															
3	10·8		9·5		8·3		6·6		4·5		2·7															
4	12·9		10·6		8·5		6·2		3·7		1·1															
5	14·0		11·1		10·3		7·9		5·8		2·8															
Total	58·8		50·4		43·5		32·1		20·5		9·1															
No. .	5		5		5		5		5		4															
Av. .	11·8		10·1		8·7		6·4		4·1		2·3															
Decade 40.																										
1	11·2		10·2		9·1		6·9		4·8		1·7															
2	14·1		13·2		12·2		10·5		8·8		6·7		4·7		2·0											
3	14·0		12·3		11·4		9·9		8·3		6·6		3·7		1·6											
4	16·0		13·8		11·6		10·0		7·8		5·2		2·3													
5	16·9		13·6		13·3		10·8		8·9		6·8		3·9		1·9											
Total	72·2		63·1		57·6		48·1		38·6		27·0		14·6		5·5											
No. .	5		5		5		5		5		5		4		3											
Av. .	14·4		12·6		11·5		9·6		7·7		5·4		3·7		1·8											

Stem Analysis Form No. 8

MEAN DIAMETER COMPUTATION FOR DECADES (50—80).

Species.—Picea Morinda. *Division.*—Chakrata.

Quality.—I. *Block & Compt.*—Kanasar, 23.

Crown class.—1*a*.

Tree No.	Height of Section (Feet) 4½	Dev.	14	Dev.	24	Dev.	34	Dev.	44	Dev.	54	Dev.	64	Dev.	74	Dev.	84	Dev.	94	Dev.	104	Dev.	114	Dev.	124	Dev.
													DECADE 50.													
1	12·6		11·8		11·1		9·8		7·4		5·1		1·9													
2	16·2		15·0		14·3		12·9		11·4		9·7		7·8		5·6		3·4		1·0							
3	16·5		14·5		13·6		12·3		10·8		9·3		6·4		4·4		1·8									
4	18·5		16·2		14·2		13·1		10·9		8·4		5·2		2·3											
5	19·3		15·6		15·3		13·1		11·7		9·6		6·9		4·6		1·2									
Total	83·1		73·1		68·5		61·2		52·2		42·1		28·2		16·9		6·4		1·0							
No. .	5		5		5		5		5		5		5		4		3		1							
Av. .	16·6		14·6		13·7		12·2		10·4		8·4		5·6		4·2		2·1		1·0							
													DECADE 60.													
1	14·7		13·8		13·1		12·3		10·1		8·1		5·2		2·4											
2	18·0		16·5		15·8		14·4		13·1		11·5		9·9		7·9		6·0		3·5		0·5					
3	19·1		16·8		15·8		14·8		13·0		11·8		9·2		7·2		4·8		2·5							
4	20·8		18·0		16·0		15·1		13·4		11·0		7·7		4·8		1·9									
5	21·7		17·5		16·9		15·1		13·7		12·1		9·5		7·2		3·7		1·1							
Total	94·3		82·6		77·6		71·7		63·3		54·5		41·5		29·5		16·4		7·1		0·5					
No. .	5		5		5		5		5		5		5		5		4		3		1					
Av. .	18·9		16·5		15·5		14·3		12·7		10·9		8·3		5·9		4·1		2·4		0·5					
													DECADE 70.													
1	16·3		15·2		14·7		14·0		12·1		10·4		7·9		5·6		2·6									
2	20·1		18·4		17·5		16·3		14·8		13·3		11·8		9·8		8·2		5·7		2·7					
3	21·3		18·4		17·8		16·3		14·9		13·8		11·3		9·5		7·1		4·5		1·7					
4	22·6		19·4		17·6		16·7		14·6		12·9		9·9		7·1		4·2		1·4							
5	23·8		19·0		18·3		16·6		15·4		14·2		11·9		9·3		6·2		3·7							
Total	104·1		90·4		85·4		79·9		71·8		64·6		52·8		41·3		28·3		15·3		4·4					
No. .	5		5		5		5		5		5		5		5		5		4		2					
Av. .	20·8		18·1		17·1		16·0		14·4		12·9		10·6		8·3		5·7		3·8		2·2					
													DECADE 80.													
1	18·5		16·6		16·1		15·3		13·8		12·3		10·0		8·0		5·5		2·4		0·3	-2				
2	21·8		19·5		18·6		17·4		16·1		14·6		13·0		11·2		9·8		7·2		4·0		2·1			
3	23·3		20·0		18·9		18·0		16·6		15·0		13·1		11·2		8·8		6·2		2·5					
4	23·7		20·3		18·6		17·8		15·7		14·2		11·7		8·9		6·0		2·8							
5	25·5		20·3		19·4		17·9		16·9		15·7		13·4		11·0		8·2		5·6		2·3					
Total	112·8		96·7		91·6		86·4		79·1		71·8		61·2		50·3		38·3		24·3		9·1	·2	2·1			
No. .	5		5		5		5		5		5		5		5		5		5		4		1			
Av. .	22·6		19·3		18·3		17·3		15·8		14·4		12·2		10·1		7·7		4·9		2·3	·5	2·1			

Stem Analysis Form No. 3.

Mean diameter Computation for decades (90—100).

Species.—Picea Morinda. *Division.*—Chakrata.

Quality.—I. *Block & Compt.*—Kanasar, 23.

Crown class.—1a.

Tree No.	4½	Dev.	14	Dev.	24	Dev.	34	Dev.	44	Dev.	54	Dev.	64	Dev.	74	Dev.	84	Dev.	94	Dev.	104	Dev.	114	Dev.	124	Dev.
													Height of Section (Feet).													
													Decade 90.													
1	0		0		0		0		0		0		0		0		0		0		0		0			
2	22·7		20·4		19·5		18·2		17·1		15·5		14·0		12·3		11·0		8·4		5·2		2·0			
3	25·7		21·8		20·6		19·8		18·3		17·1		15·2		13·0		10·7		8·0		4·4		0·8	−·1		
4	24·6		21·1		19·5		18·8		16·6		15·1		12·8		10·0		7·5		4·0							
5	27·4		21·7		20·6		19·3		18·3		17·1		15·1		12·9		10·3		7·5		4·2		2·0		0·8	−1¼
Total	100·4		85·0		80·2		76·1		70·3		64·8		57·1		48·2		39·5		27·9		13·8		5·7	−·1	0·8	−1¼
No. .	4		4		4		4		4		4		4		4		4		4		3		3		1	
Av. .	25·1		21·3		20·1		19·0		17·6		16·2		14·3		12·1		9·9		7·0		4·6		1·9	−·3	0·8	−1¼
													Decade 100.													
1	0		0		0		0		0		0		0		0		0		0		0		0		0	
2	24·2		21·5		20·7		19·3		18·0		16·6		15·1		13·5		12·1		9·6		6·4		4·0		1·0	+1½
3	0		0		0		0		0		0		0		0		0		0		0		0		0	0
4	25·6		22·5		20·6		19·6		17·7		16·2		14·2		11·3		8·9		5·3		0·7	+1½	0		0	
5	0		0		0		0		0		0		0		0		0		0		0		0		0	
Total	49·8		44·0		41·3		38·9		35·7		32·8		29·3		24·8		21·0		14·9		7·1	+1½	4·0		1·0	+1½
No. .	2		2		2		2		2		2		2		2		2		2		2		1		1	
Av. .	24·9		22·0		20·7		19·5		17·9		16·4		14·7		12·4		10·5		7·5		3·6	+·8	4·0		1·0	+1½

Stem Analysis Form No. 3.

MEAN TREE VOLUME COMPUTATION FOR DECADES (10-50).

Species.—Picea Morinda. *Division.*—Chakrata.

Quality.—I. *Block and Compt.*—Kanasar, 23.

Crown class.—1a.

Decade	Height of Section (Feet). 4½	14	24	34	44	54	64	74	84	94	104	114	124	Total Volume
10 YEARS.	4·1 0·0917 0·8253	1·9 0·0197 0·1970	2′ cone 0·5 0·0014 0·0009											Total Volume = 1·02.
20 YEARS.	8·3 0·3758 3·3822	6·6 0·2376 2·3760	4·7 0·1205 1·2050	2·4 0·0314 0·3140	3′ cone 1·0 0·0055 0·0055									Total Volume = 7·28.
30 YEARS.	11·6 0·7340 6·6060	10·1 0·5564 5·5640	8·4 0·3840 3·8490	6·5 0·2304 2·3040	4·4 0·1056 1·0560	10′ cone 3·2 0·0559 0·1863								Total Volume = 19·57.
40 YEARS.	14·4 1·1309 10·1781	12·6 0·8660 8·6600	11·3 0·6965 6·9650	9·6 0·5027 5·0270	7·7 0·3234 3·2340	5·5 0·1650 1·6500	3·2 0·0559 0·5590	4′ cone 1·6 0·0140 0·0187						Total Volume = 36·29.
50 YEARS.	16·9 1·5578 14·0202	14·7 1·1785 11·7850	13·6 1·0089 10·0890	12·2 0·8118 8·1180	10·4 0·5900 5·9000	8·5 0·3941 3·9410	6·2 0·2096 2·0960	3·6 0·0707 0·7070	6′ cone 2·0 0·0218 0·0436					Total Volume = 56·70.

Stem Analysis Form No. 3.

MEAN TREE VOLUME COMPUTATION FOR DECADES (60—100).

Species.—Picea Morinda.
Quality.—I.
Crown class.—1a.

Division.—Chakrata.
Block and Compt.—Kanasar, 23.

Tree No.	Height of Section (Feet). 4½	Dev.	14	Dev.	24	Dev.	34	Dev.	44	Dev.	54	Dev.	64	Dev.	74	Dev.	84	Dev.	94	Dev.	104	Dev.	114	Dev.	124	Dev.
60 YEARS.																										
	18·9 1·9482 17·5338		16·5 1·4849 14·8490		15·5 1·3104 13·1040		14·2 1·0997 10·9970		12·7 0·8798 8·7980		10·9 0·6481 6·4810		8·7 0·4129 4·1290		6·2 0·2096 2·0960		3·5 0·0669 0·6690		6′ cone 2·0 0·0218 0·0436							
																							Total Volume = 78·70.			
70 YEARS.																										
	20·8 2·3597 21·2373		18·1 1·7868 17·8680		17·1 1·5949 15·9490		16·0 1·3963 13·9630		14·5 1·1467 11·4670		12·8 0·8937 8·9370		10·7 0·6245 6·2450		8·3 0·3758 3·7500		5·8 0·1835 1·8350		3·1 0·0524 0·5240		5′ cone 1·6 0·0140 0·0233					
																					Total Volume = 101·80					
80 YEARS.																										
	22·6 2·7857 25·0713		19·6 2·0952 20·9520		18·5 1·8666 18·6660		17·4 1·6513 16·5130		16·0 1·3963 13·9630		14·3 1·1153 11·1530		12·4 0·8387 8·3870		10·1 0·5564 5·5640		7·7 0·3234 3·2340		5·1 0·1418 1·4180		2·2 0·0264 0·2640		8′ cone 0·8 0·0035 0·0085			
																					Total Volume = 125·19.					
90 YEARS.																										
	24·1 3·1679 28·5111		20·9 2·3825 23·8250		19·7 2·1167 21·1670		18·5 1·8666 18·6660		17·1 1·5949 15·9490		15·5 1·3104 13·1040		13·7 1·0237 10·2370		11·5 0·7214 7·2140		9·2 0·4617 4·6170		6·6 0·2376 2·3760		4·0 0·0873 0·8730		10′ cone 2·7 0·0398 0·1327			
																					Total Volume = 146·67.					
100 YEARS.																										
	25·4 3·5188 31·6692		22·0 2·6398 26·3980		20·7 2·3371 23·3710		19·5 2·0739 20·7390		18·1 1·7868 17·8680		16·5 1·4849 14·8490		14·7 1·1785 11·7850		12·6 0·8660 8·6600		10·4 0·5900 5·9000		8·0 0·3491 3·4910		5·5 0·1650 1·6500		2·9 0·0459 0·4590		6′ cone 1·6 0·0140 0·0280	
																					Total Volume = 166·87.					

Computation for bark thickness.

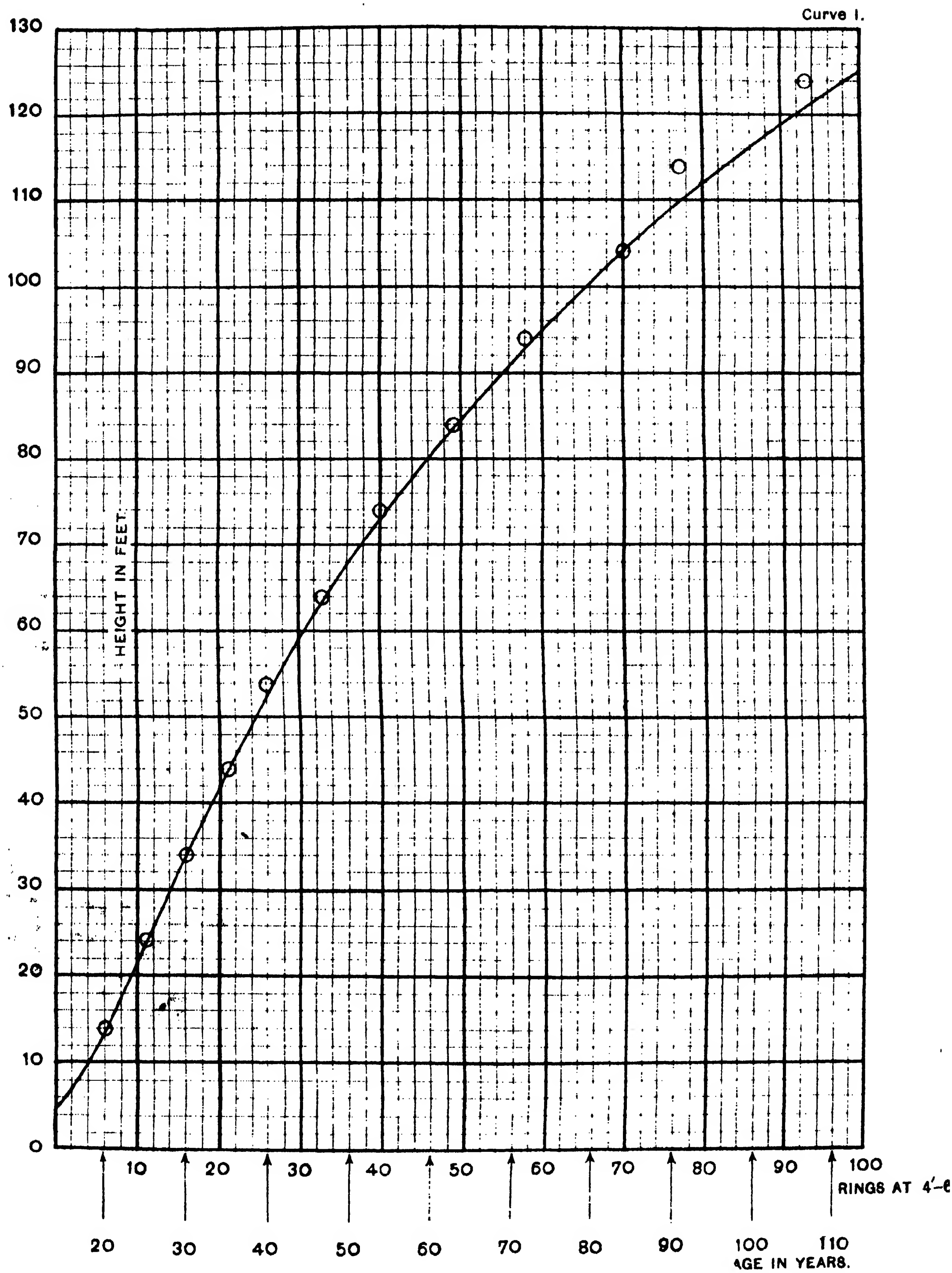
Species.—Picea Morinda. *Division.*—Chakrata.
Quality.—I. *Block and Compt.*—Kanasar, 23.
Crown class.—1a.

0·1"—4·0".		4·1"—8·0".		8·1"—12·0".		12·1"—16·0".		16·1"—20·0".		20·1"—24·0".		24·1"—28·0".		28·1"—32·0".	
D.	Bark thickness.	D.	Bark thickness.	D.	Bark thickness.	D.	Bark thickness.	D.	Bark thickness.	D.	Bark thickness.	D.	Bark thickness.	D.	Bark thickness.
3·6	0·8	6·6	0·8	11·2	0·8	15·0	0·8	19·2	1·4	22·9	1·0	26·1	1·1	28·6	1·1
1·8	0·5	5·6	1·0	9·3	0·9	14·4	1·0	17·2	0·9	21·7	1·7	26·2	1·1		
1·5	0·5	6·1	1·1	11·9	0·9	13·3	1·0	16·6	0·8	20·0	1·0	25·3	1·0		
1·7	0·5	5·3	0·8	9·2	1·1	14·3	1·1	19·5	0·9	23·1	1·4				
3·1	0·7	7·4	0·8	9·8	1·1	14·7	0·8	18·4	0·9	20·9	1·7				
0·8	0·3	5·3	0·9	11·5	1·0	12·1	1·3	16·5	0·7	20·3	0·9				
2·0	0·5			8·8	1·1	14·0	1·1	18·1	1·6	22·6	1·5				
				10·5	1·1	15·9	1·0	16·7	1·1	21·3	1·3				
						14·4	1·6	20·0	1·5	22·2	1·4				
						13·0	0·9	19·1	1·6	21·1	1·0				
								17·8	1·9						
								16·1	1·3						
								19·9	1·1						
								18·7	0·9						
								17·2	1·2						
14·0	3·8	36·3	5·4	82·2	8·0	142·0	10·6	271·0	17·8	217·0	12·9	77·6	3·2	28·6	1·1
7	7	6	6	8	8	10	10	15	15	10	10	3	3	1	1
2·0	0·5	6·1	0·9	10·3	1·0	14·2	1·1	18·1	1·2	21·7	1·3	25·9	1·1	28·6	1·1

Stem Analysis Curves.

STEM ANALYSIS.

Species – Picea Morinda. Height Age. Division Chakrata.

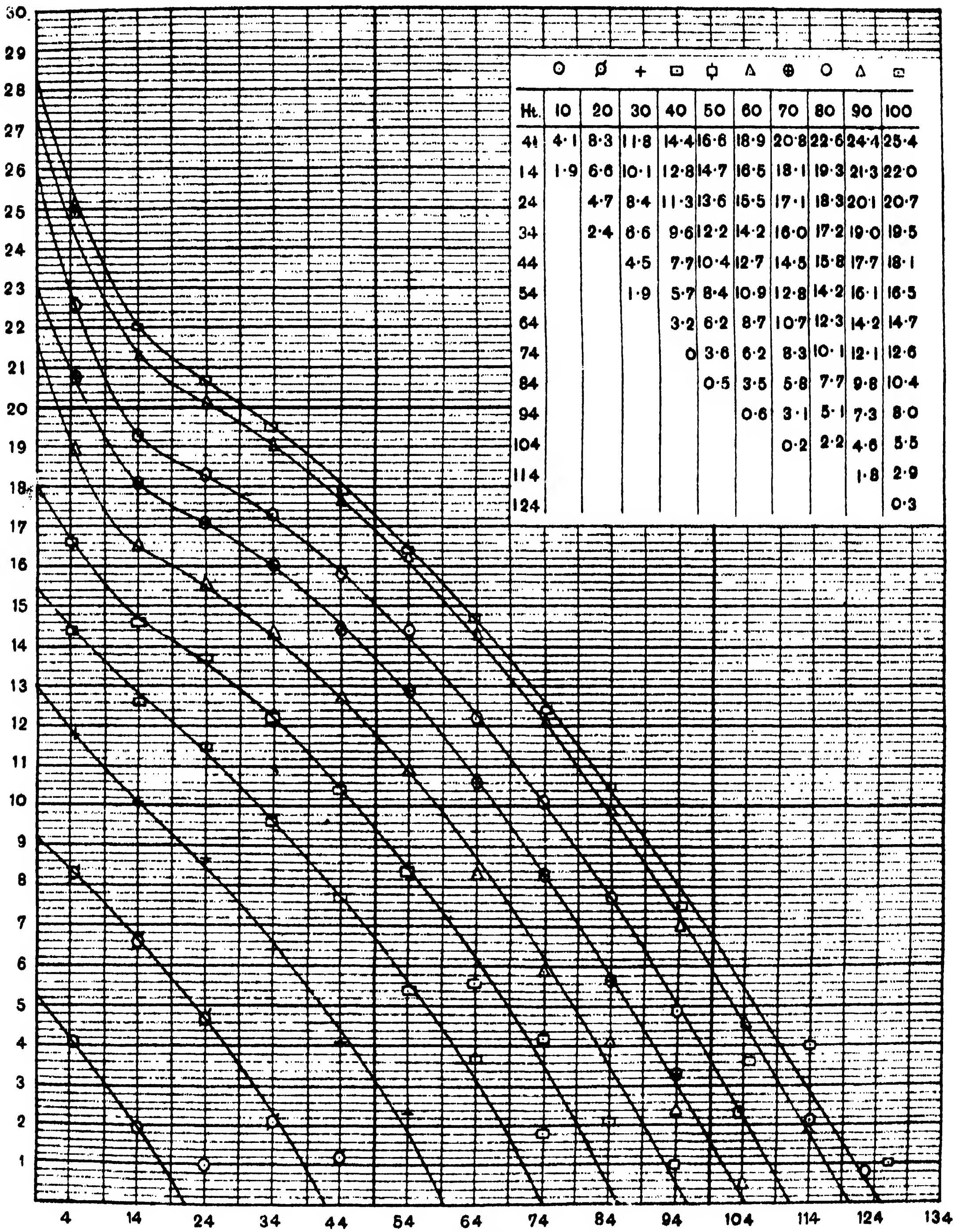


STEM ANALYSIS.

Species—Picea Morinda. Division—Chakrata.

Diameter under bark/Height (First Curve).

Curve II (Step 1)



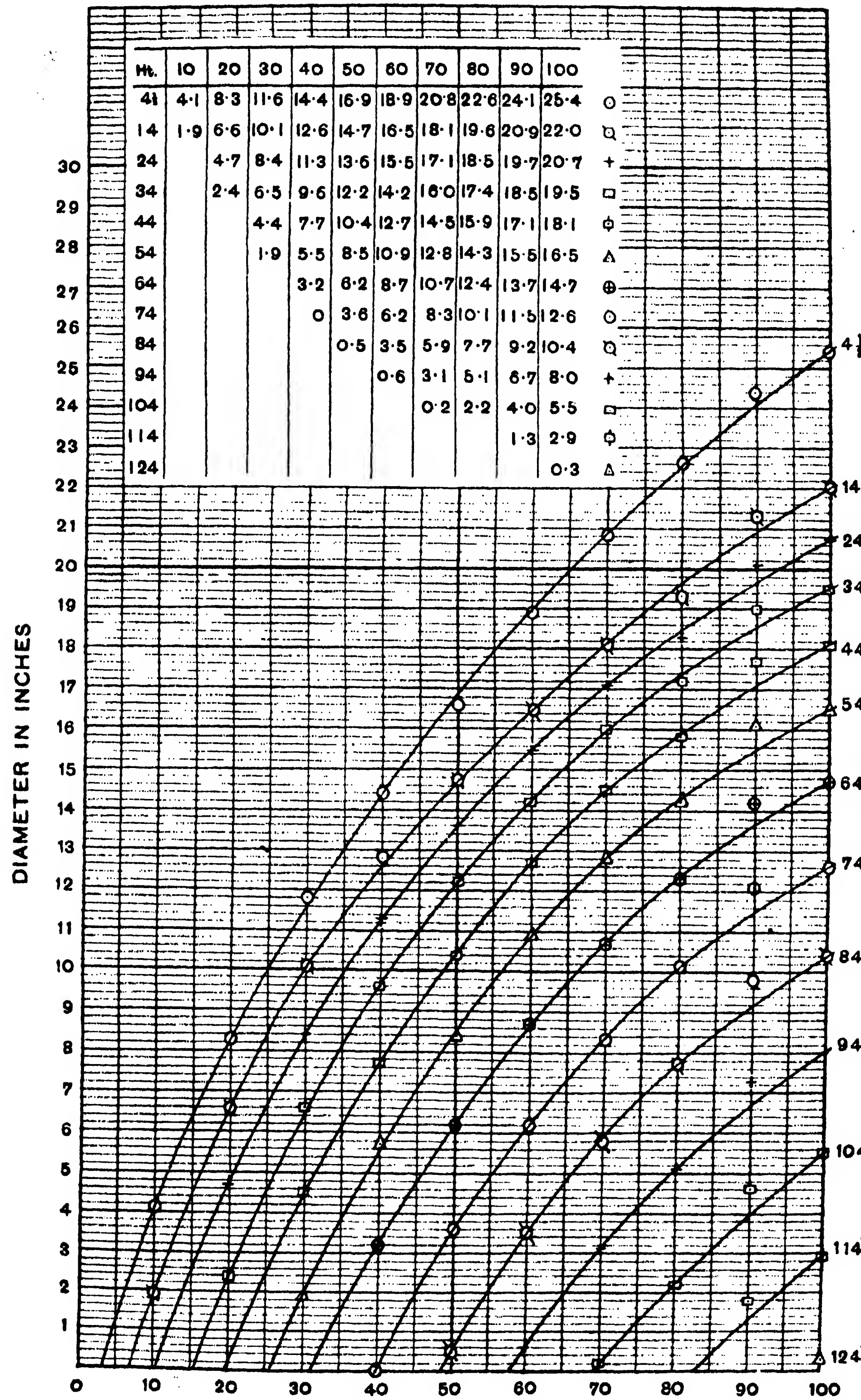
	ʘ	ø	+	⊡	ȹ	Δ	⊕	O	Δ	⊡
Ht.	10	20	30	40	50	60	70	80	90	100
41	4·1	8·3	11·8	14·4	16·6	18·9	20·8	22·6	24·4	25·4
14	1·9	6·6	10·1	12·8	14·7	16·5	18·1	19·3	21·3	22·0
24		4·7	8·4	11·3	13·6	15·5	17·1	18·3	20·1	20·7
34		2·4	6·6	9·6	12·2	14·2	16·0	17·2	19·0	19·5
44			4·5	7·7	10·4	12·7	14·5	15·8	17·7	18·1
54			1·9	5·7	8·4	10·9	12·8	14·2	16·1	16·5
64				3·2	6·2	8·7	10·7	12·3	14·2	14·7
74				0	3·6	6·2	8·3	10·1	12·1	12·6
84					0·5	3·5	5·8	7·7	9·8	10·4
94						0·6	3·1	5·1	7·3	8·0
104							0·2	2·2	4·6	5·5
114									1·8	2·9
124										0·3

Species—Picea Morinda. Division—Chakrata.

Diameter under bark/Height (Second Curve).

Curve III (Step 2)

Ht.	10	20	30	40	50	60	70	80	90	100	
4½	4·1	8·3	11·6	14·4	16·9	18·9	20·8	22·6	24·1	25·4	⊙
14	1·9	6·6	10·1	12·6	14·7	16·5	18·1	19·6	20·9	22·0	⊙
24		4·7	8·4	11·3	13·6	15·5	17·1	18·5	19·7	20·7	+
34		2·4	6·5	9·6	12·2	14·2	16·0	17·4	18·5	19·5	□
44			4·4	7·7	10·4	12·7	14·5	15·9	17·1	18·1	ϕ
54			1·9	5·5	8·5	10·9	12·8	14·3	15·5	16·5	△
64				3·2	6·2	8·7	10·7	12·4	13·7	14·7	⊕
74				0	3·6	6·2	8·3	10·1	11·5	12·6	⊙
84					0·5	3·5	5·9	7·7	9·2	10·4	⊙
94						0·6	3·1	5·1	6·7	8·0	+
104							0·2	2·2	4·0	5·5	□
114									1·3	2·9	ϕ
124										0·3	△



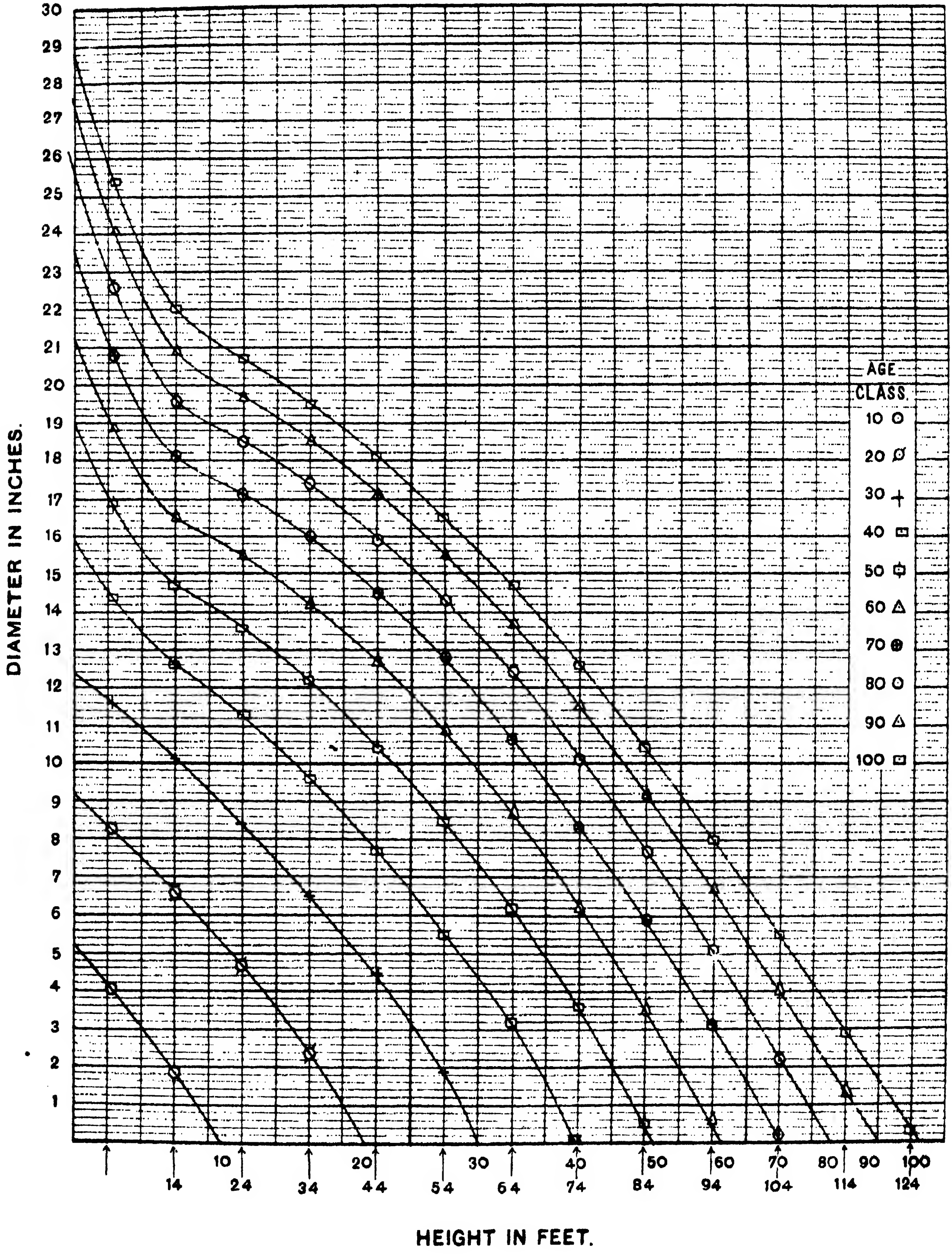
STEM ANALYSIS.

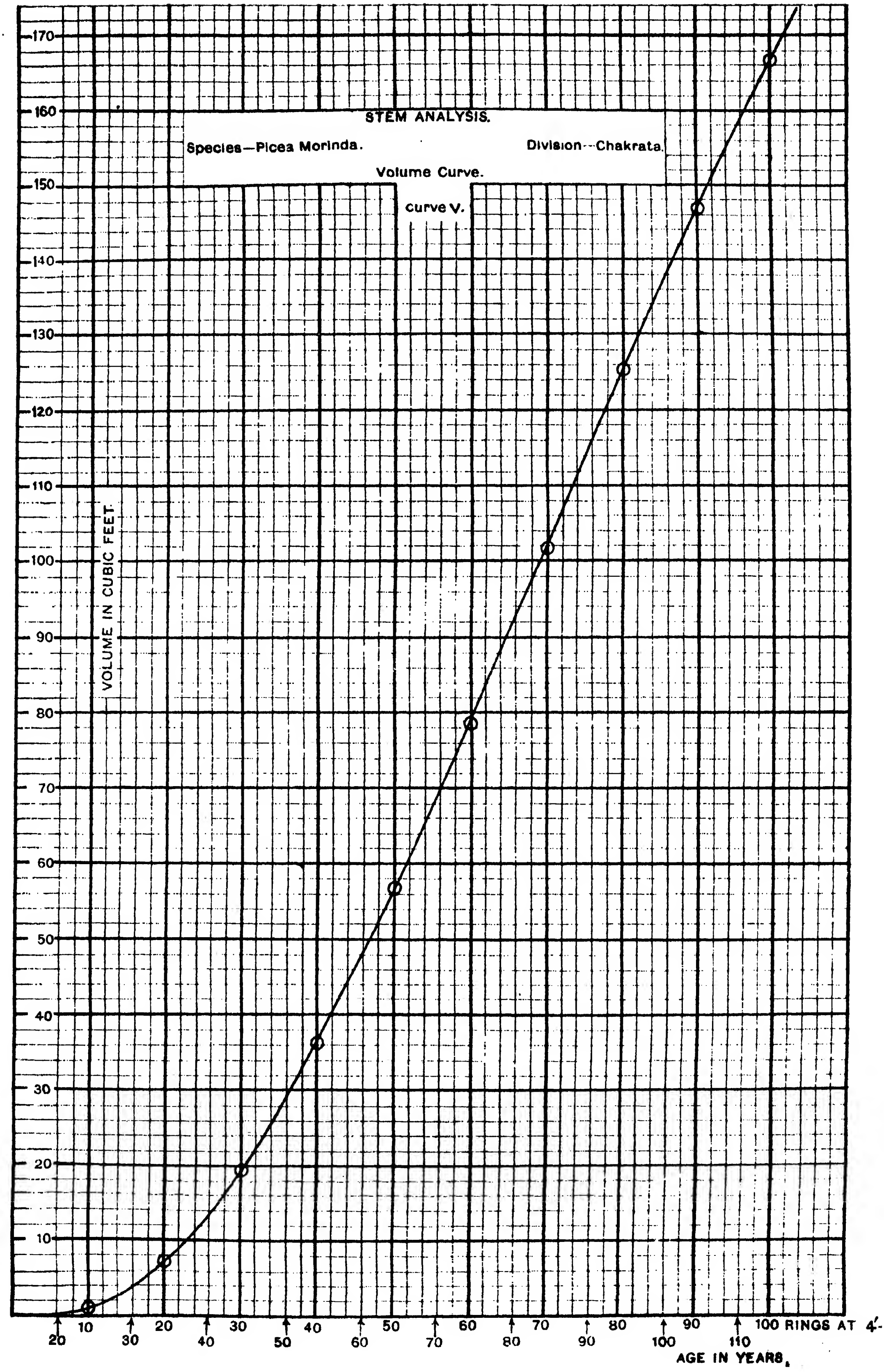
Species– Picea Morinda.

Division–Chakrata.

Diameter under bark/Height (Final Curve).

Curve IV (Step 3)

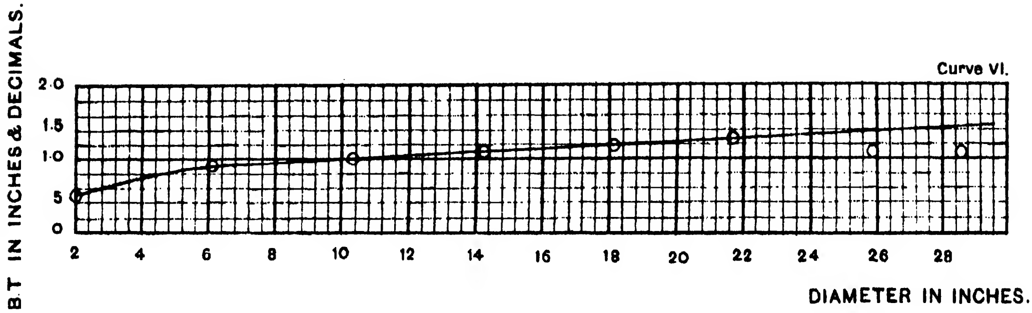



STEM ANALYSIS.
Species—Picea Morinda.
Division--Chakrata.
Volume Curve.
Curve V.
VOLUME IN CUBIC FEET
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
10 20 30 40 50 60 70 80 90 100 RINGS AT 4'
20 30 40 50 60 70 80 90 100 110
AGE IN YEARS.

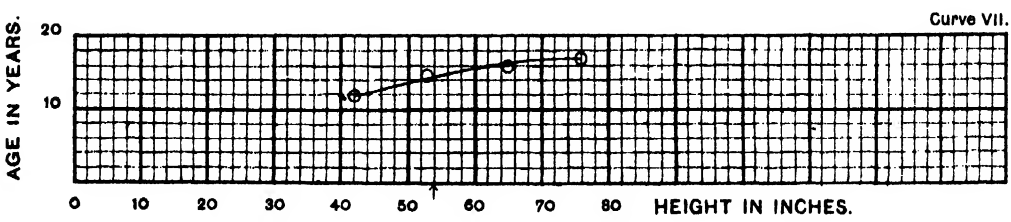
STEM ANALYSIS.

Species—Picea Morinda. Division--Chakrata.

Twice bark thickness. (B.T.)



Age/Height of seedlings.

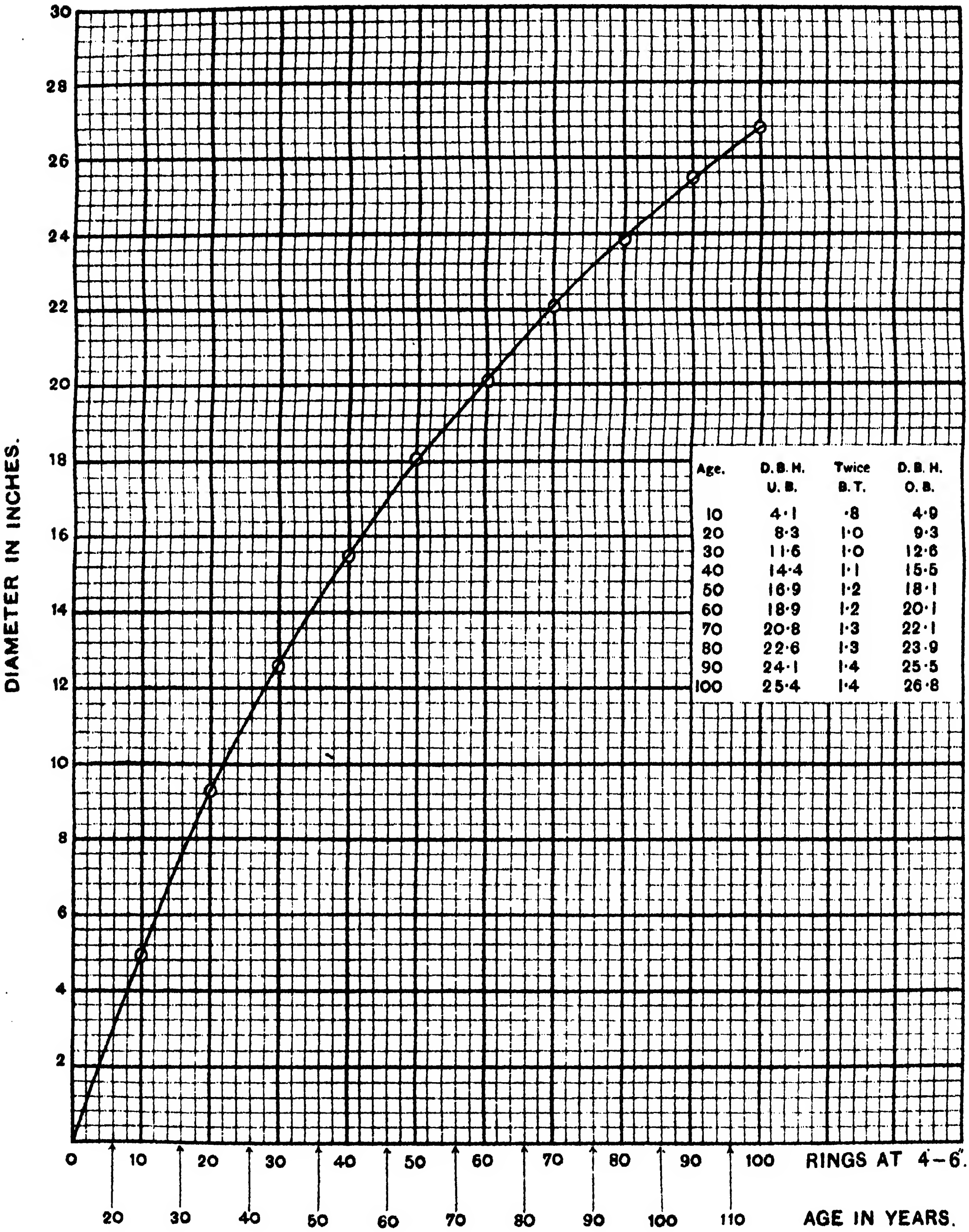


STEM ANALYSIS.

Species—Picea Morinda. Division—Chakrata.

D.B.H. (over bark)/Age.

Curve VIII



Age.	D.B.H. U.B.	Twice B.T.	D.B.H. O.B.
10	4·1	·8	4·9
20	8·3	1·0	9·3
30	11·6	1·0	12·6
40	14·4	1·1	15·5
50	16·9	1·2	18·1
60	18·9	1·2	20·1
70	20·8	1·3	22·1
80	22·6	1·3	23·9
90	24·1	1·4	25·5
100	25·4	1·4	26·8

CHAPTER IX.

Increment Borings.

(i) Objects.

1. To determine the current increment of trees of given diameter, age or crown classes as an indication of the need of thinnings or regeneration.

2. To determine the average time required for trees to pass through successive diameter classes with a view to fixing yield or rotation.

3. To determine the diameter increment of mature trees for the purpose of estimating allowance to be made for increment during a regeneration period, in regulating yield.

   The increment for a short period in the past may be assumed to be the same for a similar period in the future.

4. To determine the effect of adverse or favourable factors, and the response made to any improvement or control operations.

The advantages of increment borings as compared with stump analysis which can be used for the same purposes, are as follows :—

(a) *Control of the data.*—Since borings are made on standing trees, selection can be made of the trees definitely acceptable from the point of view of the investigation in question. The data obtained are thus more homogeneous.

(b) *Wide range of data.*—Data can be collected on any standing trees, and not only on stumps of recently felled trees.

(c) *Elimination of taper.*—Borings are taken directly at breast height, and so no taper data are required as they are in the case of stump analysis.

(d) *Economy of time and money.*—The work is quicker, both in the field and in the office.

(e) *Observations can be repeated* on the same trees at any later data.

The main relative disadvantage is the lack of knowledge of the total age of the trees examined.

(ii) Field Equipment.

(1) Pressler's borer with maker's fittings .	1	
(2) Research calliper . .	1	24″ Fromme or Flury type marked in inches and tenths.
(3) Pocket lens . . .	1	
(4) A small light box with sheets of cotton wool .	..	For holding the borings.
(5) Machine oil . . .	..	For cleaning the borer.

If properly cared for, the borer should take many hundred borings without needing to be sharpened. The greatest care should be given to avoiding any injury to the cutting edge; it requires a tool expert to sharpen it once it is blunted, and the instrument may be irremediably injured if wrongly filed.

(iii) Procedure.

(*A*) *Field work.*

(1) Typical trees with bole of regular shape at 4′ 6″ above ground level should be selected for borings. What is to be considered typical should be decided for each locality and the purpose of the investigation.

(2) The diameter classes to be taken will depend on the investigation in hand, the amount of time available, and the accuracy desired in the end results. Usually only the largest or the average classes are required, but the whole range should be covered for accurate determination of rotation.

(3) Borings should be taken at breast height; in the event of any irregularity of shape at 4′ 6″, borings should be taken sufficiently above or below that height to avoid such irregularity, and the height of the point where borings are taken should be recorded.

(4) In the case of species with buttress formation at the base, borings should be taken on the stem just above the point where the buttress formation ends. Height of borings should be recorded for each tree.

(5) At least two borings should be taken, one at each end of a normally developed diameter. In the case of markedly eccentric or irregular stems, two or more pairs of borings (at the two ends of diameters) should be taken.

(6) The number of trees measured should be 50 in the first instance. *See* (*f*) below (p. 101).

(7) All borings should be taken at right angles to the surface.

(8) The number of rings to be bored will depend on the investigation: in most cases either 10 rings or ½″ depth is required, and a 50 per cent. margin should be allowed.

(9) A convenient form in which to record the field data as collected, is the following:—

Increment Borings.

Species.—

Division.—

Range, Block, Compt.— *Initials and date.*—

Tree No.	Diameter at b.h. over bark.		Rings per ...... inch of radius, or width in inches of ...... rings.
	Measurements.	Average.	

The headings can be repeated three or four times horizontally across the page, and different diameter classes can be kept in different vertical columns if desired.

(B) *Computations.*

For each tree, measurements of pairs of opposite borings should be totalled and averaged.

(*a*) *Current annual growth per cent.* in diameter (P) for each diameter, age, or crown class concerned, is calculated from the following formulæ, and compared with predetermined standard values.

(1) *Pressler's approximate formula.*

If n=number of rings in the last unit length of radius, and d and D are the initial and final diameters, then

$$P=\frac{200}{n}\ \frac{D-d}{D+d}$$

(2) *Compound interest formula.*

$$\frac{D}{d}=(1{\cdot}0\,p)^n$$

(Tables for values of $(1{\cdot}0\ p)^n$ for different values of p are appended (Appendix I, p. 107). From these tables, the values of P can be read off direct.)

The increment per cent. or relative increment of diameter falls off from the beginning, and can be represented by a curve of hyperbolic shape.

Relative increment in sectional area above d.b.h. increases with the height.

The mean relative increment of the stem is found at a point halfway between the base of the crown and breast height.

(*b*) For determination of the *average time taken by trees in passing through successive diameter classes*, periodic current increment (say for 10 years) and average diameter should be calculated for the mean tree of each diameter class, and a smooth increment curve drawn (Curve A, p. 105).

Ex. 33. *Borings were taken on a number of trees of* Bombax malabaricum. *The data for 3 trees in each 4" diameter class, for the past 5 and 10 years are tabulated on p. 103, and worked up with Curves A and B on p. 105 as described in the following paragraphs. The final curve and tabulated data after correction for bark thickness are not reproduced.*

The increment curve should then be transformed into a growth curve by the following steps :—

(1) Starting with the lowest diameter plotted on the increment curve (7·1"), its increment during the period is read off directly (2·3") ; this is added to the original diameter to obtain the final diameter at the end of the period (9·4"). Increment against this diameter is read off again (2·7") and similarly added ; this process is continued for the range of values available for the increment curve.

(2) The diameter values so obtained are plotted against a succession of equidistant points spaced at intervals corresponding to the number of years in the period, and the growth curve drawn through the plotted points. (Curve B.)

(3) The time axis of the curve is corrected to read age by shifting the zero point to the left by the necessary number of units corresponding to the estimated time required to reach the lowest diameter plotted (6 years).

(4) Bark thickness is added from bark thickness tables if available; otherwise, bark thickness is separately measured on the borings or as an independent investigation; values so obtained are curved over diameters, and smooth values read off and added.

(c) *Rotation* can be obtained directly from the final curve of the preceding section by reading the values for age against the selected rotation diameter.

Another approximation of rotation from measurements on mature trees can be made by the application of the following approximate formula, in which w is the average width of the annual rings for any given depth of boring (say 1"), a is the allowance for years to attain breast height, and D the selected rotation diameter.

$$\text{Rotation} = a + \frac{D}{2w}$$

Ex. 34. Bombax *logs of 90" girth and over could not be dealt with by the machinery available in a match-making plant; required to determine the maximum permissible rotation. In the case of buttressed trees, 90" girth refers to the point of measurement just above the buttress, and the d. b. h. corresponding to this calculated on the available data is taken as 30".*

Average width of annual rings measured on borings taken with Pressler's borer for last 1" of radius was 0·3" and the age to reach 4' 6" is taken as 4 years.

$$w = 0{\cdot}3''$$

$$D = 30$$

$$a = 4$$

$$\begin{aligned}\text{Rotation} &= 4 + \frac{30}{2 \times 0{\cdot}3}\\ &= 4 + 50\\ &= 54 \text{ years.}\end{aligned}$$

Rotation age for maximum volume production is the age at which mean annual increment and current annual increment are equal. As total age is not known, the former cannot be accurately determined, but for a first approximation, it may be assumed that the two are equal in trees which are visibly neither immature nor overmature, the estimate being checked by comparison of width of rings in a few sample trees of each type.

Culmination of current diameter increment occurs after the culmination of height increment.

Excluding the irregular portion of the tree at the base affected by root swelling, the width of each annual ring varies directly with the extent of the leaf surface or the circumference of the crown at the time the ring was laid down. (*Pressler's Law of Growth.*)

Diameter increment at any point of the stem is determined by the position of the crown, which is in turn determined by the available growing space. In the case of open crops, the diameter increment is greater in the lower portion of the stem, while in the case of crops of moderate density, the thickness of annual rings may be uniform throughout. Suppressed trees have greater diameter increment in the upper than in the lower portions of the bole.

(*d*) *Increment during a regeneration period.*—The field data averaged by diameter classes and curved, will give diameter increment for the period in question (half the regeneration period) for the mean tree of each diameter class. With the help of the stand table and volume tables, this may be converted directly into the volume increment required.

Alternatively, borings having been taken from a sufficient number of representative trees, a single increment per cent. may be deduced by Pressler's or the compound interest formulæ given above, and applied to the whole crop in question. Increment per cent. in basal area is double the diameter increment per cent., but the volume increment per cent. is dependent on changes in height (which in the case of mature crops may be disregarded) and form factor as well as diameter. If form factor is assumed not to change significantly, volume increment per cent. may also be taken as double the diameter increment per cent. ; this is generally permissible.

(*e*) *Effect of influences applied to crops.*—To investigate such problems, the procedure is exactly as under head (*a*) above.

(*f*) *Determination of the number of trees required in each inch class.*—The number of trees required in each inch class should be determined by the usual method described on p. 41, taking radial measurements or counts of annual rings as the vari-

Increment Borings.

Species.—Bombax malabaricum.

Division.—Haldwani.

Range and Block.—Chakata, Gaula.

Initials and date.—*P. Q. R.*

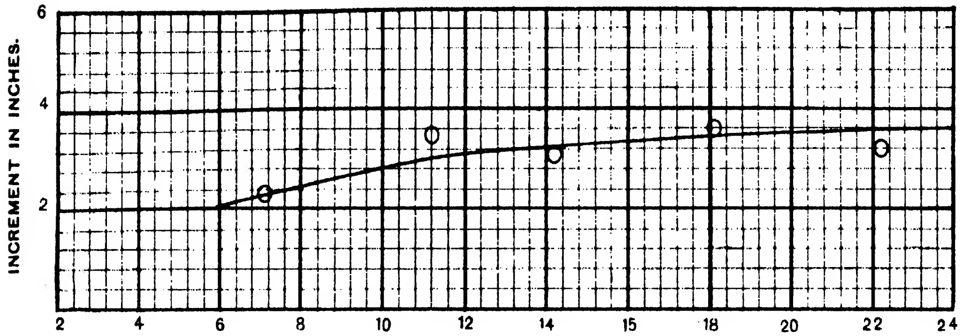
Tree No.	D. B. H. Over bark. Measurements.	D. B. H. Over bark. Average.	Rings per inch of radius. Width in inches of 5 rings. 1st.	Rings per inch of radius. Width in inches of 5 rings. 2nd.	Tree No.	D. B. H. Over bark. Measurements.	D. B. H. Over bark. Average.	Rings per inch of radius. Width in inches of 5 rings. 1st.	Rings per inch of radius. Width in inches of 5 rings. 2nd.
	4·1″—8·0″.					**16·1″—20·0″.**			
1	7·4 / 7·4	7·4	1·20 / 1·00	2·40 / 1·95	10	16·0 / 16·8	16·4	2·10 / 2·00	3·55 / 3·20
2	6·7 / 6·2	6·5	1·10 / 1·30	2·15 / 3·00	11	19·3 / 18·1	18·7	1·30 / 1·25	2·00 / 2·70
3	7·6 / 6·9	7·3	0·90 / 1·35	2·25 / 2·60	12	18·8 / 19·7	19·3	1·95 / 2·20	3·25 / 3·30
Total .	..	21·2	6·85	14·35	Total .	..	54·4	10·80	18·60
Average .	..	7·1	2·28	4·78	Average .	..	18·1	3·60	6·20
	8·1″—12·0″.					**20·1″—24·0″.**			
4	11·2 / 11·1	11·2	2·10 / 1·60	3·30 / 2·30	13	20·1 / 21·2	20·7	2·15 / 1·80	3·35 / 4·40
5	11·1 / 10·2	10·7	1·55 / 1·20	2·30 / 2·50	14	22·2 / 22·0	22·1	1·30 / 1·90	2·35 / 3·75
6	11·2 / 12·1	11·7	1·90 / 2·10	3·65 / 3·10	15	23·5 / 24·3	23·9	1·15 / 1·40	3·20 / 3·15
Total .	..	33·6	10·45	17·15	Total .	..	66·7	9·70	20·20
Average .	..	11·2	3·48	5·72	Average .	..	22·2	3·23	6·73
	12·1″—16·0″.								
7	11·9 / 12·5	12·2	1·15 / 1·50	2·65 / 2·60	..	..	..	..	..
8	14·5 / 14·6	14·6	1·50 / 1·60	3·10 / 2·85	..	..	..	..	..
9	15·5 / 15·8	15·7	1·90 / 1·60	4·00 / 4·10	..	..	..	..	..
Total .	..	42·5	9·25	19·30	..	..	..	..	..
Average .	..	14·2	3·08	6·43	..	..	..	..	..

Increment and Growth curves based on Increment Borings.

Species—Bombax malabaricum. Division—Haldwani.

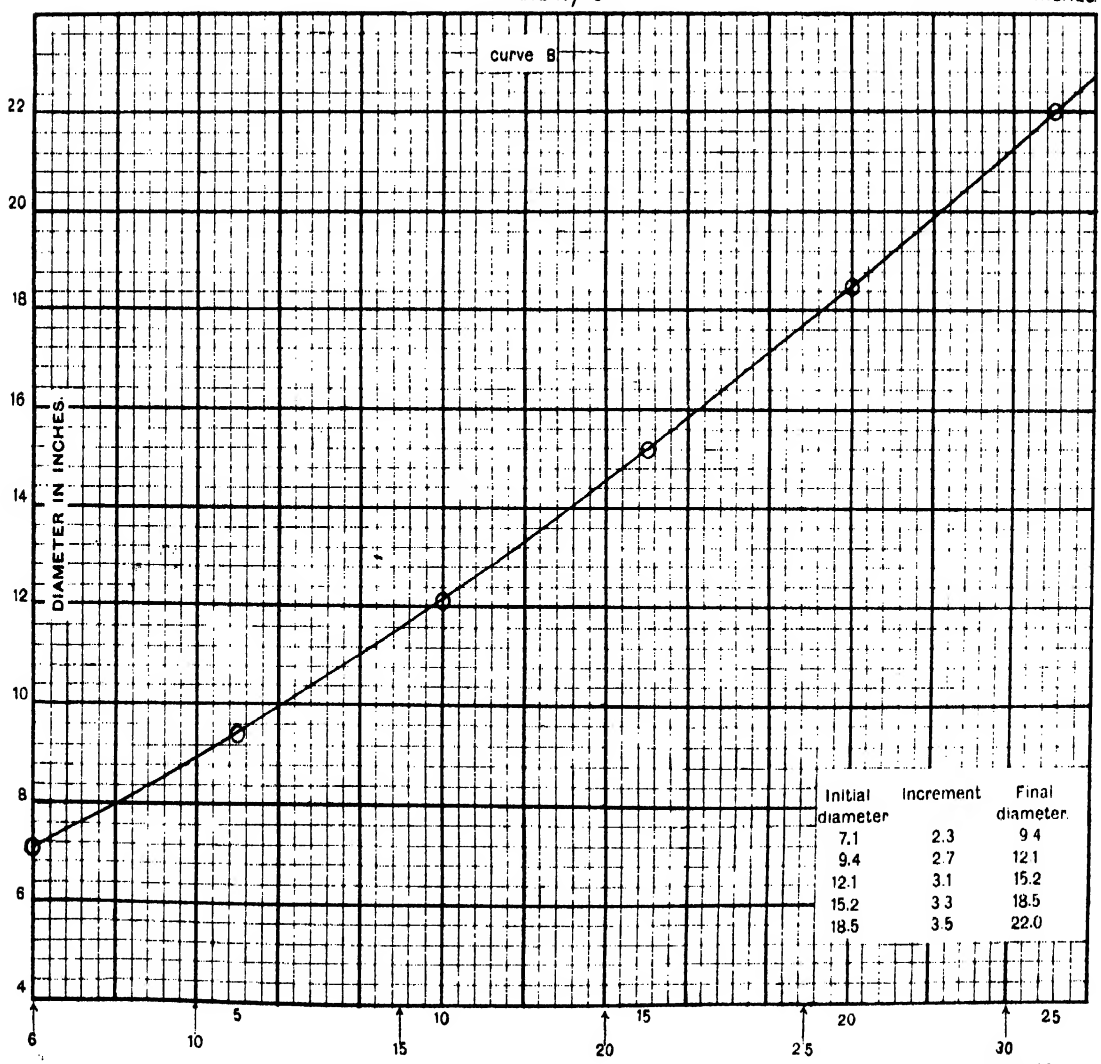
DIAMETER INCREMENT.

Curve A.



D. B. H./Age

DIAMETER IN INCHES.



Initial diameter	Increment	Final diameter.
7.1	2.3	9 4
9.4	2.7	12 1
12.1	3.1	15.2
15.2	3 3	18.5
18.5	3.5	22.0

APPENDIX I.

VALUES OF FACTOR (1·0 p).^{n}

[Required in connection with annual growth per cent., *see* p. 99.]

Years.	P. 0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0
	$\frac{D}{d}$ – (1·0 p).^{n}									
2	1·002	1·004	1·006	1·008	1·010	1·012	1·014	1·016	1·018	1·020
3	1·003	1·006	1·009	1·012	1·015	1·018	1·021	1·024	1·027	1·030
4	1·004	1·008	1·012	1·016	1·020	1·024	1·028	1·032	1·036	1·041
5	1·005	1·010	1·015	1·020	1·025	1·030	1·035	1·041	1·046	1·051
6	1·006	1·012	1·018	1·024	1·030	1·037	1·043	1·049	1·055	1·062
7	1·007	1·014	1·021	1·028	1·036	1·043	1·050	1·057	1·065	1·072
8	1·008	1·016	1·024	1·032	1·041	1·049	1·057	1·066	1·074	1·083
9	1·009	1·018	1·027	1·037	1·046	1·055	1·065	1·074	1·084	1·094
10	1·010	1·020	1·030	1·041	1·051	1·062	1·072	1·083	1·094	1·105
11	1·011	1·022	1·034	1·045	1·056	1·068	1·080	1·092	1·104	1·116
12	1·012	1·024	1·037	1·049	1·062	1·074	1·087	1·100	1·114	1·127
13	1·013	1·026	1·040	1·053	1·067	1·081	1·095	1·109	1·124	1·138
14	1·014	1·028	1·043	1·057	1·072	1·087	1·103	1·118	1·134	1·149
15	1·015	1·030	1·046	1·062	1·078	1·094	1·110	1·127	1·144	1·161
16	1·016	1·032	1·049	1·066	1·083	1·100	1·118	1·136	1·154	1·173
17	1·017	1·035	1·052	1·070	1·088	1·107	1·126	1·145	1·165	1·184
18	1·018	1·037	1·055	1·075	1·094	1·114	1·134	1·154	1·175	1·196
19	1·019	1·039	1·059	1·079	1·099	1·120	1·142	1·163	1·186	1·208
20	1·020	1·041	1·062	1·083	1·105	1·127	1·150	1·173	1·196	1·220
25	1·025	1·051	1·078	1·105	1·133	1·161	1·190	1·220	1·251	1·282
30	1·030	1·062	1·094	1·127	1·161	1·197	1·233	1·270	1·308	1·348
	1·1	**1·2**	**1·3**	**1·4**	**1·5**	**1·6**	**1·7**	**1·8**	**1·9**	**2·0**
2	1·022	1·024	1·026	1·028	1·030	1·032	1·034	1·036	1·038	1·040
3	1·033	1·036	1·040	1·043	1·046	1·049	1·052	1·055	1·058	1·061
4	1·045	1·049	1·053	1·057	1·061	1·066	1·070	1·074	1·078	1·082
5	1·056	1·061	1·067	1·072	1·077	1·083	1·088	1·093	1·099	1·104
6	1·068	1·074	1·081	1·087	1·093	1·100	1·107	1·113	1·120	1·126
7	1·080	1·087	1·095	1·102	1·110	1·118	1·125	1·133	1·141	1·149
8	1·091	1·100	1·109	1·118	1·126	1·135	1·144	1·153	1·163	1·172
9	1·103	1·113	1·123	1·133	1·143	1·154	1·164	1·174	1·185	1·195
10	1·116	1·127	1·138	1·149	1·161	1·172	1·184	1·195	1·207	1·219
11	1·128	1·140	1·153	1·165	1·178	1·191	1·204	1·217	1·230	1·243
12	1·140	1·154	1·168	1·182	1·196	1·210	1·224	1·239	1·253	1·268
13	1·153	1·168	1·183	1·198	1·214	1·229	1·245	1·261	1·277	1·294
14	1·166	1·182	1·198	1·215	1·232	1·249	1·266	1·284	1·301	1·319
15	1·178	1·196	1·214	1·232	1·250	1·269	1·288	1·307	1·326	1·346
16	1·191	1·210	1·230	1·249	1·269	1·289	1·310	1·330	1·351	1·373
17	1·204	1·225	1·246	1·267	1·288	1·310	1·332	1·354	1·377	1·400
18	1·218	1·240	1·262	1·284	1·307	1·331	1·355	1·379	1·403	1·428
19	1·231	1·254	1·278	1·302	1·327	1·352	1·378	1·404	1·430	1·457
20	1·245	1·269	1·295	1·321	1·347	1·374	1·401	1·429	1·457	1·486
25	1·315	1·347	1·381	1·416	1·451	1·487	1·524	1·562	1·601	1·641
30	1·388	1·430	1·473	1·518	1·563	1·610	1·658	1·708	1·759	1·811

APPENDIX I—*contd.*

VALUES OF FACTOR $(1\cdot0\ p)^n$—*contd.*

$\frac{D}{d} = (1\cdot0\ p)^n$

Years.	p. 2·1	2·2	2·3	2·4	2·5	2·6	2·7	2·8	2·9	3·0
2	1·042	1·044	1·047	1·049	1·051	1·053	1·055	1·057	1·059	1·061
3	1·064	1·067	1·071	1·074	1·077	1·080	1·083	1·086	1·090	1·093
4	1·087	1·091	1·095	1·100	1·104	1·108	1·112	1·117	1·121	1·126
5	1·110	1·115	1·120	1·126	1·131	1·137	1,142	1·148	1·154	1·159
6	1·133	1·139	1·146	1·153	1·160	1·167	1·173	1·180	1·187	1·194
7	1·157	1·165	1·173	1·181	1·189	1·197	1·205	1·213	1·222	1·230
8	1·181	1·190	1·200	1·209	1·218	1·228	1·238	1·247	1·257	1·267
9	1·206	1·216	1·227	1·238	1·249	1·260	1·271	1·282	1·293	1·305
10	1·231	1·243	1·255	1·268	1·280	1·293	1·305	1·318	1·331	1·344
11	1·257	1·270	1·284	1·298	1·312	1·326	1·341	1·355	1·370	1·384
12	1·283	1·298	1·314	1·329	1·345	1·361	1·377	1·393	1·409	1·426
13	1·310	1·327	1·344	1·361	1·379	1·396	1·414	1·432	1·450	1·469
14	1·338	1·356	1·375	1·394	1·413	1·432	1·452	1·472	1·492	1·513
15	1·366	1·386	1·407	1·427	1·448	1·470	1·491	1·513	1·535	1·558
16	1·394	1·417	1·439	1·462	1·485	1·508	1·532	1·556	1·580	1·605
17	1·424	1·448	1·472	1·497	1·522	1·547	1·573	1·599	1·626	1·653
18	1·454	1·480	1·506	1·533	1·560	1·587	1·615	1·644	1·673	1·702
19	1·484	1·512	1·540	1·569	1·599	1·629	1·659	1·690	1·721	1·754
20	1·515	1·545	1·576	1·607	1·639	1·671	1·704	1·737	1·771	1·806
25	1·681	1·723	1·766	1·809	1·854	1·900	1·947	1·994	2·044	2·094
30	1·865	1·921	1·978	2·037	2·098	2·160	2·224	2·290	2·357	2·427

Years.	3·1	3·2	3·3	3·4	3·5	3·6	3·7	3·8	3·9	4·0
2	1·063	1·065	1·067	1·069	1·071	1·073	1·075	1·077	1·080	1·082
3	1·096	1·099	1·102	1·106	1·109	1·112	1·115	1·118	1·122	1·125
4	1·130	1·134	1·139	1·143	1·148	1·152	1·156	1·161	1·165	1·170
5	1·165	1·171	1·176	1·182	1·188	1·193	1·199	1·205	1·211	1·217
6	1·201	1·208	1·215	1·222	1·229	1·236	1·244	1·251	1·258	1·265
7	1·238	1·247	1·255	1·264	1·272	1·281	1·290	1·298	1·307	1·316
8	1·277	1·287	1·297	1·307	1·317	1·327	1·337	1·348	1·358	1·369
9	1·316	1·328	1·339	1·351	1·363	1·375	1·387	1·399	1·411	1·423
10	1·357	1·370	1·384	1·397	1·411	1·424	1·438	1·452	1·466	1·480
11	1·399	1·414	1·429	1·445	1·460	1·476	1·491	1·507	1·523	1·539
12	1·442	1·459	1·476	1·494	1·511	1·529	1·546	1·564	1·583	1·601
13	1·487	1·506	1·525	1·544	1·564	1·584	1·604	1·634	1·644	1·665
14	1·533	1·554	1·575	1·597	1·619	1·641	1·663	1·686	1·709	1·732
15	1·581	1·604	1·627	1·651	1·675	1·700	1·725	1·750	1·775	1·801
16	1·630	1·655	1·681	1·707	1·734	1·761	1·788	1·816	1·844	1·873
17	1·680	1·708	1·737	1·765	1·795	1·824	1·855	1·885	1·916	1·948
18	1·732	1·763	1·794	1·825	1·857	1·890	1·923	1·957	1·991	2·026
19	1·786	1·819	1·853	1·888	1·923	1·958	1·994	2·031	2·069	2·107
20	1·842	1·878	1·914	1·952	1·990	2·029	2·068	2·108	2·149	2·191
25	2·145	2·198	2·252	2·307	2·363	2·421	2·480	2·541	2·603	2·666
30	2·499	2·573	2·649	2·727	2·807	2·889	2·974	3·061	3·151	3·243

APPENDIX I—*contd.*

VALUES OF FACTOR (1·0 p)^n—*contd.*

Years.	P.									
	4·1	4·2	4·3	4·4	4·5	4·6	4·7	4·8	4·9	5·0
	$\frac{D}{d}$=(1·0 p).^{n}									
2	1·084	1·086	1·088	1·090	1·092	1·094	1·096	1·098	1·100	1·103
3	1·128	1·131	1·135	1·138	1·141	1·144	1·148	1·151	1·154	1·158
4	1·174	1·179	1·183	1·188	1·193	1·197	1·202	1·206	1·211	1·216
5	1·223	1·228	1·234	1·240	1·246	1·252	1·258	1·264	1·270	1·276
6	1·273	1·280	1·287	1·295	1·302	1·310	1·317	1·325	1·332	1·340
7	1·325	1·334	1·343	1·352	1·361	1·370	1·379	1·388	1·398	1·407
8	1·379	1·390	1·400	1·411	1·422	1·433	1·444	1·455	1·466	1·477
9	1·436	1·448	1·461	1·473	1·486	1·499	1·512	1·525	1·538	1·551
10	1·195	1·509	1·524	1·538	1·553	1·568	1·583	1·598	1·613	1·629
11	1·556	1·572	1·589	1·606	1·623	1·640	1·657	1·675	1·693	1·710
12	1·620	1·638	1·657	1·677	1·696	1·715	1·735	1·755	1·775	1·796
13	1·686	1·707	1·729	1·750	1·772	1·794	1·817	1·840	1·862	1·886
14	1·755	1·779	1·803	1·827	1·852	1·877	1·902	1·928	1·954	1·980
15	1·827	1·854	1·880	1·908	1·935	1·963	1·992	2·020	2·049	2·079
16	1·902	1·931	1·961	1·992	2·022	2·054	2·085	2·117	2·150	2·183
17	1·980	2·013	2·046	2·079	2·113	2·148	2·183	2·219	2·255	2·292
18	2·061	2·097	2·134	2·171	2·208	2·247	2·286	2·325	2·366	2·407
19	2·146	2·185	2·225	2·266	2·308	2·350	2·393	2·437	2·182	2·527
20	2·234	2·277	2·321	2·366	2·412	2·458	2·506	2·554	2·603	2·653
25	2·731	2·797	2·865	2·934	3·005	3·078	3·153	3·229	3·307	3·386
30	3·338	3·430	3·536	3·639	3·745	3·854	3·966	4·082	4·200	4·322

Years.	5·1	5·2	5·3	5·4	5·5	5·6	5·7	5·8	5·9	6·0
2	1·105	1·107	1·109	1·111	1·113	1·115	1·117	1·119	1·122	1·124
3	1·161	1·164	1·168	1·171	1·174	1·178	1·181	1·184	1·188	1·191
4	1·220	1·225	1·229	1·234	1·239	1·244	1·248	1·253	1·258	1·262
5	1·282	1·288	1·295	1·301	1·307	1·313	1·319	1·326	1·332	1·338
6	1·348	1·356	1·363	1·371	1·379	1·387	1·395	1·403	1·411	1·419
7	1·417	1·426	1·436	1·445	1·455	1·464	1·475	1·484	1·494	1·504
8	1·489	1·500	1·512	1·523	1·535	1·546	1·558	1·570	1·582	1·594
9	1·565	1·578	1·592	1·605	1·619	1·633	1·647	1·661	1·675	1·689
10	1·644	1·660	1·676	1·692	1·708	1·724	1·741	1·757	1·774	1·791
11	1·728	1·747	1·765	1·783	1·802	1·821	1·840	1·859	1·879	1·898
12	1·816	1·837	1·858	1·880	1·901	1·923	1·945	1·967	1·990	2·012
13	1·909	1·933	1·957	1·981	2·006	2·031	2·056	2·081	2·107	2·133
14	2·007	2·033	2·061	2·088	2·116	2·144	2·173	2·202	2·231	2·261
15	2·109	2·139	2·170	2·201	2·233	2·264	2·297	2·330	2·363	2·397
16	2·216	2·250	2·285	2·320	2·355	2·391	2·428	2·465	2·502	2·540
17	2·329	2·367	2·406	2·445	2·485	2·525	2·566	2·608	2·650	2·693
18	2·448	2·490	2·533	2·577	2·621	2·667	2·712	2·759	2·806	2·854
19	2·573	2·620	2·668	2·716	2·766	2·816	2·867	2·919	2·972	3·026
20	2·704	2·756	2·809	2·863	2·918	2·974	3·030	3·088	3·147	3·207
25	3·468	3·551	3·637	3·724	3·813	3·905	3·998	4·094	4·192	4·292
30	4·447	4·576	4·708	4·844	4·984	5·128	5·275	5·427	5·583	5·744

APPENDIX I—*contd.*

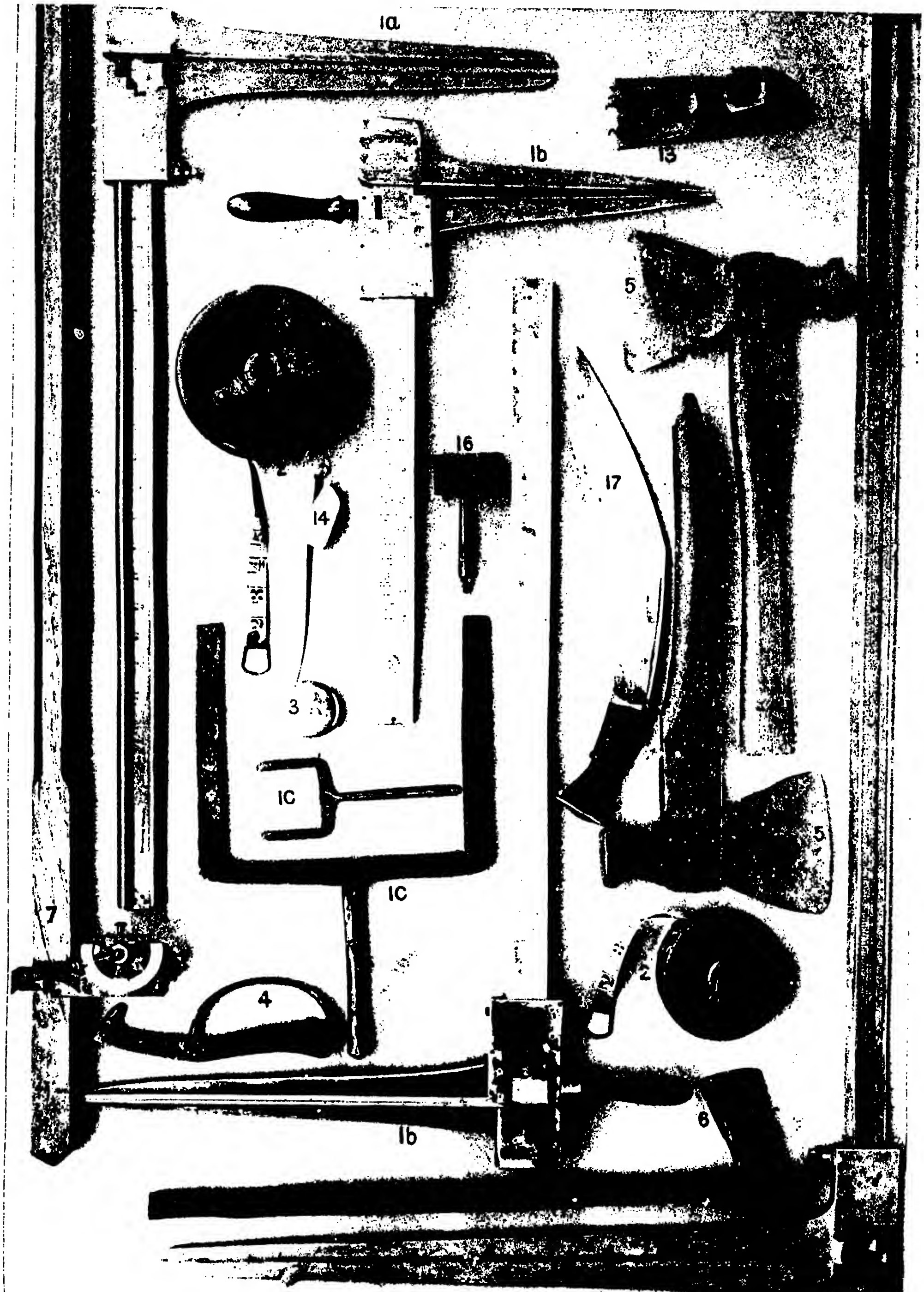
VALUES OF FACTOR $(1{\cdot}0\ p)^n$—*contd.*

P.

$\frac{D}{d} = (1{\cdot}0\ p).^n$

Years.	6·2	6·4	6·6	6·8	7·0	7·2	7·4	7·6	7·8	8·0
2	1·128	1·132	1·136	1·141	1·145	1·149	1·153	1·158	1·162	1·166
3	1·198	1·205	1·211	1·218	1·225	1·232	1·239	1·246	1·253	1·260
4	1·272	1·282	1·291	1·301	1·311	1·321	1·331	1·340	1·350	1·360
5	1·351	1·364	1·377	1·389	1·403	1·416	1·429	1·442	1·456	1·469
6	1·435	1·451	1·467	1·484	1·501	1·518	1·535	1·552	1·569	1·587
7	1·524	1·544	1·564	1·585	1·606	1·627	1·648	1·670	1·692	1·714
8	1·618	1·643	1·667	1·693	1·718	1·744	1·770	1·797	1·824	1·851
9	1·718	1·748	1·778	1·808	1·838	1·870	1·901	1·933	1·966	1·999
10	1·825	1·860	1·895	1·931	1·967	2·004	2·042	2·080	2·119	2·159
11	1·938	1·979	2·020	2·062	2·105	2·149	2·193	2·238	2·285	2·332
12	2·058	2·105	2·153	2·202	2·252	2·303	2·355	2·409	2·463	2·518
13	2·186	2·240	2·295	2·352	2·410	2·469	2·530	3·592	2·655	2·720
14	2·321	2·383	2·447	2·512	2·579	2·647	2·717	2·789	2·862	2·937
15	2·465	2·536	2·608	2·683	2·759	2·837	2·918	3·000	3·085	3·172
16	2·618	2·698	2·780	2·865	2·952	3·042	3·134	3·228	3·326	3·426
17	2·781	2·871	2·961	3·060	3·159	3·261	3·366	3·474	3·585	3·700
18	2·953	3·055	3·160	3·268	3·380	3·495	3·615	3·738	3·865	3·996
19	3·136	3·250	3·368	3·490	3·617	3·747	3·882	4·022	4·166	4·316
20	3·330	3·458	3·590	3·728	3·870	4·017	4·170	4·328	4·491	4·661
25	4·499	4·716	4·942	5·179	5·427	5·687	5·958	6·242	6·538	6·849
30	6·078	6·431	6·803	7·197	7·612	8·051	8·514	9·003	9·518	10·063

Years.	8·2	8·4	8·6	8·8	9·0	9·2	9·4	9·6	9·8	10·0
2	1·171	1·175	1·179	1·184	1·188	1·192	1·197	1·201	1·206	1·210
3	1·267	1·274	1·281	1·288	1·295	1·302	1·309	1·317	1·324	1·331
4	1·371	1·381	1·391	1·401	1·412	1·422	1·432	1·443	1·453	1·464
5	1·483	1·497	1·511	1·525	1·539	1·553	1·567	1·581	1·596	1·611
6	1·605	1·622	1·641	1·659	1·677	1·696	1·714	1·733	1·752	1·772
7	1·736	1·759	1·782	1·805	1·828	1·852	1·876	1·900	1·921	1·949
8	1·879	1·906	1·935	1·964	1·993	2·022	2·052	2·082	2·113	2·144
9	2·033	2·067	2·101	2·136	2·172	2·208	2·245	2·282	2·320	2·358
10	2·199	2·240	2·282	2·324	2·367	2·411	2·456	2·501	2·547	2·594
11	2·380	2·428	2·478	2·529	2·580	2·633	2·687	2·741	2·797	2·853
12	2·575	2·632	2·691	2·751	2·813	2·875	2·939	3·004	3·071	3·138
13	2·786	2·854	2·923	2·993	3·066	3·140	3·215	3·293	3·372	2·452
14	3·014	3·093	3·174	3·257	3·342	3·429	3·518	3·609	3·702	3·798
15	3·261	3·353	3·447	3·544	3·642	3·744	3·848	3·955	4·065	4·177
16	3·529	3·635	[illegible]	3·855	3·970	4·088	4·210	4·335	4·463	4·595
17	3·818	3·940	[illegible]·065	4·195	4·328	4·465	4·606	4·751	4·900	5·054
18	4·131	4·271	4·415	4·564	4·417	4·875	5·039	5·207	5·381	5 560
19	4·470	4·630	4·795	4·965	5·142	5·324	5·512	5·707	5·908	6·116
20	4·837	5·019	5·207	5·402	5·604	5·814	6·030	6·255	6·487	6·728
25	7·173	7·5[illegible]2	7·866	8·236	8·623	9·027	9·450	9·892	10·353	10·835
30	10·637	11·243	11·882	12·556	13·268	14·018	14·809	15·643	1[illegible]·522	17·449



Field Equipment for Sample Plot and other statistical work.

1a. Elmy's Callipers, graduated arm of wood, brass bound. 1b. Fromme's Callipers, all metal. 1c. Fixed Callipers of soft iron. 2. Linen Tapes 100' and 50'. 3. Steel Tape. 4. Tree Scribe (folding pattern). 5. Felling axes. 6. Light trimming axes. 7. Abney's Level with stand. 13. Adze. 14. Chalk. 16. Optical Square. 17. Khukri.

Opposite page 111.

CHAPTER X.

Sample Plots for Crop Increment in Even-aged Crops.

(i) Objects.

1. The determination of crop increment at all stages of development of even-aged crops.

2. The comparison of crop increment of even-aged crops with the same origin and treatment but on different qualities of locality.

3. The comparison of the influence on crop increment of even-aged crops of different methods of regeneration and treatment.

(ii) Field Equipment, Staff, and Time required.

(a) *Field Equipment.*

1. Research callipers . .	3	Two 32″ or 24″, all metal (Fromme type), one 14″ (Fromme or Flury type).
2. Fixed iron callipers (Prongs) . . .	2	8 and 2 inches.
3. Steel measuring tapes .	2	12 foot long, graduated in inches and tenths.
4. Linen measuring tapes .	2	100 foot and 50 foot.
5. Tree scribe . . .	1	
6. Abney's level . . .	1	Model 265F with stand.
7. Surveyor's rods . .	4	
8. Surveyor's cross stave .	1	
9. Plane table with alidade and compass . .	1	If required for mapping position of the trees in the plot.
10. Optical square . .	1	Ditto.
11. Pocket compass . .	1	
12. Felling axes . . .	6	
13. Small sharp axe or adze .	1	For cleaning rings for ring counting.
14. Khukri	1	
15. Chalk	1 lb.	For every 100 trees to be numbered: good quality necessary.
16. White paint . . .	5 lbs.	
17. Linseed oil . . .	$1\frac{1}{2}$ lbs.	
18. Slide Rule . . .	1	10″ scale.
19. Sample Plot Forms 8 and 7 bound in books, and Forms 2, 3, and 11. Exp. Plot Form 5 .	..	As required.
20. Section paper . . .	..	,,
21. Field note books . .	..	,,

It has proved impossible so far to make or procure satisfactory large size callipers with the graduated arm in wood, however stiffened. The 32″ calliper should accordingly always be all metal (e.g., Fromme's). The small 14″ calliper can be made quite well in wood with brass bearing surfaces and strengthening, and the wooden model has the advantage of being both less brittle and more easily repaired. The middle size can be constructed of wood only if well made.

(1) *Flury callipers*; graduated arm wooden, brass bound; fixed and moveable arms of aluminium; 32″, 24″, 14″, approximate cost inclusive of freight and duty delivered in India, Rs. 55, 48, and 40 respectively.

(2) *Fromme callipers*; all aluminium; 34″, 24″, 14″; approximate cost inclusive of canvas cases, freight and duty delivered in India, Rs. 40, 34 and 30 respectively.

(3) *Locally prepared callipers*; copied from Flury's but fixed and moveable arm of teak encased in brass; can usually be supplied by Central Silviculturist at a cost of about Rs. 17 and 20 for 14″ and 24″ callipers respectively.

(4) *Tree scribes* are best obtained by having an imported sample copied by a skilled *mistri*.

(5) The model 265F *Abney's level* is a marked advance on the older models, and is capable of giving good results with the use of stand and screw adjustment. *Cf.* Mathematical Instrument Office list for 1928. The cost is Rs. 40 for the level and Rs. 5-8-0 for the stand.

(6) A serviceable *plane table* is obtainable from the Mathematical Instrument Office for Rs. 11-8-0, the folding alidade costing Rs. 18 extra and the stand Rs. 16.

(7) The *optical square* in a sling leather case is obtainable from the Mathematical Instrument Office for Rs. 7-12-0.

The whole equipment of instruments for a party (excluding axes) costs about Rs. 300. *See* Plate V.

(*b*) *Staff required.*

The 3rd Silvicultural Conference (1929) passed a resolution (7, Resolution 1*b*, p. 17) to the effect that a sample plot field party should consist of one Provincial Service Officer or picked Ranger, and 3 men of the Forester type, whilst the reporting committee further strongly recommended the addition of a man of Deputy Ranger status. Duties may be distributed as follows:—

Officer-in-charge party . .	Selection of plots, demarcation, marking, thinning, selection of sample trees, Form 2, (mapping, recording).
Deputy Ranger . . .	Callipering main crop; measurement of sample trees and thinnings; mapping.
Forester I	Area measurements; recording measurements of standing crop and sample trees.

Forester 2	Painting numbers and cross marks. For a regular party, a less trained or temporary hand can be taught to do this work.
Forester 3	Supervision of labour on demarcation, felling and preparing trees for measurement.
Permanent coolies . . .	As a rule six can be usually kept with the party.

(c) *Time required for laying out plots.*

A full remeasurement of an existing plot can always be completed in one day. Two small plots close together can sometimes be dealt with in one day. A new plot can be completed in a day provided the number of trees is not too large, and that much time is not lost in searching for the plot itself or for sample trees outside the plot, but it is usually difficult to complete a tree map unless an extra assistant is available to do it. In a general way, it should be taken that a new plot will probably require two days.

An interim measurement can be accomplished in half a day. An assistant of average ability should be able to paint cross mark and number on 30 to 40 trees per hour of actual work.

(d) *Species for which Sample Plots are required.*

At the 1929 Silvicultural Conference, the following resolution was adopted.

"Resolved that Provincial Silviculturists in co-operation should complete as soon as possible the series of sample plots required for the compilation of yield tables for the following species :—

I. In Natural Forest.—Acacia Catechu, Alnus nepalensis, Eugenia Jambolana (coppice), Quercus incana, Terminalia myriocarpa and *Terminalia tomentosa.*

II. In Plantations.—Acacia arabica, Alnus nepalensis, Casuarina, Cryptomeria, Dalbergia latifolia, Gmelina arborea, Michelia Champaca, Michelia excelsa and *Terminalia myriocarpa.*

The following additional species should be considered as of importance second only to the aforementioned.

I. In Natural Forest.—Dipterocarpus pilosus, Dipterocarpus turbinatus, Lagerstroemia Flos-Reginae, and *Populus euphratica.*

II. In Plantations.— Cinnamomum Cecidodaphne.

Work on other species should as far as necessary be subordinated to these.

Statistics of growth for single trees are similarly required as soon as possible for the following species :—

Adina cordifolia, Dalbergia latifolia, Gmelina arborea, Ougeinia dalbergioides, Pterocarpus Marsupium, and *Trewia nudiflora.*"

(iii) Field Work for Selection and First Measurement.

Sample plots are of three kinds :—

(1) Permanent sample plots maintained for a varying period of years for remeasurement.

(2) Temporary plots measured (standing) once only.

(3) Clear-felled plots measured once after felling.

The prescriptions of this Section (iii) and Section (iv) following it apply to Permanent and Temporary plots, Section v, p. 124, to the remeasurement of Permanent sample plots, and Section viii, p. 134 to special procedure for clear-felled plots.

Ex. 35. *The 1920 and 1925 records and computations for Sample Plot No. 1 of Upper Bashahr division, Punjab, are reproduced on pp. 145 to 216 and should be consulted as illustrating the following Field Rules and Computation steps.*

(*a*) *Selection of plots.*

(1) Plots should be selected in crops of all ages, and should be well distributed over the whole range of quality, types, and geographical distribution of the species.

(2) A working copy of the height-age diagram for the species in question, showing the points for all existing sample plots, should be maintained for use in the forest, and consulted for every proposed new plot. Plots of the province or region should be differentiated from those outside it. If the estimated age and quality of the latter is already well represented, time can be better utilised elsewhere.

(3) Plots should be laid out in even-aged crops, the conception even-aged being interpreted with reference to the customary regeneration period for the species.

(4) Plots should be selected as far as possible in fully stocked crops. (No allowance may be made for incomplete stocking).

(5) When, owing to a lack of fully stocked crops, plots have to be laid out in open crops, the stocking should be as uniform as possible, large gaps and patchy growth being avoided.

Difficulty will always be experienced in finding enough acceptable plots of all ages for the lower qualities, and for the higher ages of the better qualities. The difficulty is usually irregularity of stocking, and it is often necessary to lower the standard demanded both as regards shape and size of plot, and regularity and completeness of stocking, to complete the series of plots. It may be accepted that plots of low quality will in practice be always more open than better quality crops of the same average age or diameter.

Greater apparent irregularity is permissible in the case of quite young crops, as much evening out takes place with further development. A common example is the small semi-blank or stunted patch where a seed tree has recently been removed.

(6) Trees at the edge of a crop or with crowns spreading into an adjacent large gap should be avoided. *See* Plate VI.

(7) Whenever an area which has been selected as suitable for laying out plots is large enough for making a pair or set of plots with the same initial conditions but

Photo. H. G. Champion.

Sample Plot 9, Chakrata division, United Provinces, in *Pinus excelsa*: Quality 0·6 I, age 53 years, crop height 87 ft., crop diameter 13·5 ins. This plot infringes Field Rule 6 and snow break has resulted from the exposure of the edge of the plot to wind. A photo. was taken from the same spot 12 years previously.

Opposite page 115.

with different kind or grade of thinning, such a pair or set of plots should be laid out on the accepted lines.

(8) Plots may be selected in mixed crops, i.e., in crops in which more than one species contributes to an important extent to the main canopy, where such mixtures are of common occurrence and of importance.

Interpretation and application of the results obtained are however very difficult, and in the present state of knowledge, more useful information will be obtained from pure crops, i.e., crops in which one species greatly predominates.

Ex. 36. Dalbergia Sissoo *and* Acacia Catechu; Dalbergia Sissoo *and* Morus alba; Pinus excelsa *and* Cedrus Deodara.

Coppice crops are very frequently composed of mixed species, but owing to the short life of the crop and the consequent far less interference with spontaneous growth, sample plots (to be clear-felled at the end of the rotation) may prove quite useful.

(b) *Number of Plots required.*

(9) Ideally, there should be about two standard plots for each decade for each quality, so that after two or three remeasurements, complete overlapping will result: in practice more will be required to compensate for unavoidable irregularity of distribution, stocking, etc. For a given thinning regime, 100 plots should be adequate for one species.

(10) A greater number of plots representing the best and lowest qualities should be aimed at, as until several remeasurements have been made, the trend of all curves derived from the plot data is largely decided by the limiting points.

(11) In a given region (province), it is desirable to cover the whole range for a species independently of the plots in other regions. A much smaller number of plots will suffice if plots of similar quality exist in other regions; 40 or 50 (suitably distributed) may be suggested.

(c) *Shape of Plots.*

(12) Plots should always have rectilinear boundaries with the angle between any two sides not less than 30°. Pronounced re-entrant angles should be avoided.

A less satisfactory outline has often to be accepted for plots of age or quality difficult to obtain.

(13) The sides of a plot, and the necessary number of diagonals to divide it completely into triangular portions, should be measured by tape to the nearest whole foot, the shortest diagonals being taken by preference.

(14) The slopes of sides and diagonals should be measured by means of an Abney's level, or any other instrument of equal accuracy, whenever the average slope exceeds 10°

(15) The actual lengths of sides and diagonals and their slopes should be measured, not the horizontal projections.

These measurements are recorded on a diagrammatic sketch map for purposes of calculation of area. *See* Rule 66, p. 122 and Computation Step 1, p. 125. The procedure prescribed for measuring the area of plots has been found the quickest and most easily checked.

(d) *Size of Plots.*

(16) Plots should as far as possible be half an acre or more in area. Smaller area is of less importance in the case of small trees, but may prevent maintenance of the plot after a few remeasurements. Above half an acre, uniformity of stocking and availability of sample trees is more important than larger area.

Experience teaches that under the conditions prevalent in Indian forests, it is impossible to insist on even a half-acre minimum; in fact, except in plantations, this figure is less often attained than not. In quite young crops, the same degree of accuracy is obtainable with ¼ acre plots, and with older crops, a pair of plots approximating half an acre each will give more valuable information than one plot of about one acre. European investigations tend to indicate that ½ hectare or 1¼ acre, has been found the optimum there as regards consistency in results.

(17) The number of dominant trees which should be taken as an absolute minimum for maturing and mature crops is 25.

(e) *The surround.*

(18) Whenever possible, plots should be provided with a surrounding strip (the '*surround*') to be treated in the same way as the plots. This strip should be of sufficient area to provide some at least of the necessary sample trees unlikely to be obtainable from the plot itself; the surround need not be of even width, but on an average it should equal the height of the crop at the time of laying out the plot, at the same time being not less than 12 yards wide.

The surround can very rarely serve both functions of supplying sample trees not available in the plot itself, and of ensuring that the actual plot is only the central portion of an area of forest under absolutely uniform treatment. The sample trees needed are nearly always those of big diameter, and their removal from the surround at once makes it different from the plot. The surround can however at least help in the desired direction, and it protects the plot from damage from fellings in the surrounding forest.

(f) *Demarcation and numbering.*

(19) The whole area including the surround should first be roughly demarcated by painting white rings at breast height on a few of the outermost trees. *See* Plate VII.

(20) The boundary lines of the plot itself should then be selected and marked by means of trenches, approximately one foot wide by 1 foot deep. *See* Plate VII. Where erosion is to be feared, these may have to be omitted, or may be replaced by intermediate posts smaller than the corner posts, at about 20′ intervals.

Photo. R. P. Bahuguna, F. R. I.

Sample Plot 35. Dehra Dun division, United Provinces, in *Terminalia tomentosa* : age 48 years, crop height 96 ft., crop diameter 14·1 ins. Illustrating the demarcation (corner-post and trench), surround (tree on right), and number board.

Opposite page 117.

(21) The boundaries of plots should be so placed as to coincide as far as possible with the outer limits of the projected crowns of the marginal trees.

Particularly with small plots, care is required that the boundary includes the whole area primarily utilised by the trees inside it. In cases of doubt, the error should be kept on the conservative side by taking the boundary further out.

(22) The corners of the plot should be marked by means of durable wooden posts serially numbered ; *see* Plate VII. Where suitable posts are not available, masonry pillars should be erected.

(23) Demarcation of the surround should be completed by painting white rings at breast height on as many trees as necessary to let it be clearly seen what trees are included.

(24) The number of a plot should be indicated on a board or enamel plate fixed on any convenient and conspicuous position near or in the plot. It will be found helpful to add the year of laying out to the plot number board.

(24*a*) Sample plots should be serially numbered, separately in each division ; the numbers should never be changed, nor should the number of an abandoned plot be reallotted to a new one.

(g) Thinnings and treatment of understory.

(25) The kind, grade and frequency of thinning to be done should be recorded in the files, and strictly adhered to. A copy of the thinning scale adopted is appended to these rules as Appendix V, p. 217. *See* also (7, p. 222). Chapter XI deals with special thinning research.

For coppice crops, the standard thinning scale only provides for the later thinnings, and makes no special provision for the customary reduction of the number of shoots per stool. Reduction of the number of shoots to 3, 2 or 1 should be investigated as though they were extra thinning grades ; likewise the removal of all small shoots irrespective of the number of dominating ones.

In mixed crops, it is essential that a clearly defined policy should be laid down for thinning treatment as affecting differently the several species of which the crop is composed.

(26) As far as possible, the plots should be brought into a normal condition when first laid out, but over-stocking may take two or even three thinnings to adjust.

The work necessary when a plot is first laid out is usually that of regularising it by the removal of single trees not merging with the rest, by opening out local crowded groups to more or less the condition of the rest of the plot and by removing of injured trees, etc. Great care must be taken not to open out a plot too rapidly, an operation which may easily ruin a plot for the very purpose for which it is taken up.

(27) Thinnings should normally be made when the plot is laid out and thereafter at 10-year intervals, except that :—

(i) For over-stocked plots which cannot be brought to a normal condition when first laid out, the second interval should also be one of 5 years if the condition of the crop then permits of further thinning.

(ii) With young crops of such species as are thinned 5-yearly in divisional practice, this period may be adopted for as many intervals as customary or desirable.

(iii) With short rotation coppice crops, a special thinning cycle is sometimes desirable; *see* p. 228.

(28) What is advisable as regards retention, removal and measurement of a lower storey must vary with species, locality and conditions; under conditions favouring luxuriant vegetation, it is often best to remove it to facilitate work, particularly as it will usually very quickly be replaced by new growth. *See* Plate VIII. Under unfavourable conditions, it is generally better to retain it as additional soil protection and where local conditions render retention of the lower canopy layers desirable for fear of damage by snow, etc., this should be done in the sample plots also.

(*h*) *Painting cross mark.*

(29) All green trees which are included within the limits of a plot, and the measurements of which are to be recorded, should be painted with a cross mark at 4′ 6″, except that:—

(i) When the bole is abnormal at 4′ 6″, the height of the cross mark should be altered as in General Rules 4-6, p. 9.

(ii) When a lower storey is composed entirely of subsidiary species, it need not be cross marked; cf. Rule 35 below.

(iii) When trees of the principal species or species represented in the main canopy are relegated to the lower story, they must be cross marked, the foregoing rule (ii) still supplying to any subsidiary species present.

(iv) Trees under 2″ d.b.h. when definitely relegated to the under story (cf. Rule 35 below), need not be cross marked.

(v) Coppice plots should be dealt with exactly like seedling forest, reading 'shoot' for 'tree'. Breast height is accordingly measured from the ground, and not from the level of the stool.

Special care is required that the bark is not unduly scraped for painting on the cross mark, and above all that the cambium is not cut. Numerous examples have been met with where light *khukri* or *dah* cuts had been used to indicate the position of the cross mark, and a reduction of 0·1″ or 0·2″ in the diameter measurement caused thereby in some cases, and in others, where the cut penetrated to the cambium, pustular swellings had formed by the next measurement rendering measurement difficult and doubtful. (Deodar seems particularly liable to this.)

(30) The cross marks should be on the uphill side on hilly ground, and all facing the same way in plots on level ground.

(31) If a paint mark is inadequate, a nail should be inserted 18″ vertically above the centre of the cross mark.

If good paint (and oil) is used, painted cross mark will usually remain clear enough for the 5-year period, except in the dampest types of forest and

Photo, T. B. Chitrakar, F. R. I.

Sample Plot 7, Sivok, Kurseong division, Bengal, in *Shorea robusta*; Quality I, age 67 years, crop height 92 ft., crop diameter 11·1 ins. In this damp type of forest complete clearing of the undergrowth is helpful (Field Rule 28).

Opposite page 119.

with some species which constantly shed their bark. When a nail is necessary, a 4″ wire nail is recommended. Insertion at a distance less than 18″ from the cross mark is liable to effect the diameter at the latter point. Copper nails obviate danger to saws later, but may conceivably affect the tree or corrode rapidly.

(j) *Numbering.*

(32) All trees on which the cross mark has been painted should be serially numbered, except that :—

(i) Until the smallest trees in the main canopy reach 4″ diameter, no numbering will be done (but only enumeration).

(ii) In the case of coppice crops which it is intended to clear fell at the next measurement, numbering is not necessary.

(33) When once numbering is done, all trees with cross marks must be numbered.

(34) In coppice crops, the numbering should be done serially for all shoots bearing a cross mark (*See* Rule 29 v). In recording, the numbers referring to a single stool should be bracketted together.

(35) Where a second story is distinguished, whether of the same species as the top story or not, the trees bearing cross marks should be similarly numbered, preferably continuing the sequence of the principal crop, and it should be clearly stated on Form 3 which numbers belong to the understory : trees without cross marks should be enumerated only.

(36) The numbers should be on the same side of the tree as the cross mark, and are conveniently based on a horizontal line 6″ above the breast height point.

(37) The outer dead bark may be carefully trimmed off with a sharp instrument to give a smooth surface for painting, but great care should be taken that no living tissues are injured or exposed.

(38) On hilly ground, numbering should start from above and should proceed stripwise along contour lines ; on level ground, numbering should run in strips parallel to one side of the plot.

(39) If paint numbers are inadequate, the number should be stamped on or punched out of a metal plate hung on the nail 18″ above the cross mark.

When number plates are necessary, rectangular pieces of 1/16″ gauge sheeting 3″×2″ are recommended, the numbers being impressed with dies.

Care is required that in trimming the bark for painting on the number, the bark at the level of the cross mark is not affected.

(k) *Measurement of the standing crop.*

(40) Breast height diameter should be measured and recorded for all trees painted with cross marks.

In the field, it is convenient to use books of Sample Plot Form 8 for recording, the data being copied later on Form 3.

Under Rules 69 and 75, diameters of trees marked for thinnings at first measurement should be on a separate copy of Sample Plot Form 3. At remeasurement, this is recorded on the first main crop Form 3 in the Column provided for the purpose.

Callipers should be accurately adjusted before commencing measurements in each plot, and checked again on completion. If the latter check reveals an error exceeding 0·05″ for the average diameter, the plot should be recallipered.

For a discussion on the relative merits of tapes and callipers, *see* Proc. Silv. Conf., 1929, pp. 156-160.

When any doubt exists as to the measurement to be recorded, the smallest alternative should be accepted.

(41) In crops of small trees not numbered, the results of enumeration in 1″ diameter classes should be recorded on the same Form 3 ; similarly for trees without cross marks in the understory.

(42) Crown class according to the standardised tree classification should be recorded for every tree for which diameter is separately recorded. *Vide* Appendix V, p. 217A. Crown classes of trees should be judged *after* felling the thinnings.

(*l*) *Selection of sample trees.*

(43) Sample trees should in the first place be selected from among the thinnings marked in the plot ; thinnings should not be felled until sample trees have been selected.

(44) Enough sample trees are needed for drawing the height/diameter curve with requisite accuracy over the greater part of the diameter range of the crop, in particular the parts of the curve corresponding to the mean diameters of the groups in which the trees will probably be classified, (cf. p. 143). Not less than 6 sample trees should be selected and measured, and 12 properly selected are usually enough.

(45) If the necessary sample trees are not available from trees marked for thinnings in the plot, the rest may be selected in the surround. If the required series is still incomplete, one must go beyond the surround for the remainder but should remain as close to the plot as possible.

Where it is necessary to go out of sight of the plot itself in the search for sample trees, the average height of the trees of the diameter in question standing in the plot should be measured, and no tree should be accepted as a sample till its height has been found to be in agreement within 3 per cent. of what is required.

(46) A sample tree of a given diameter should be representative of its diameter class in height, form, and crown development.

(47) In view of the ever increasing difficulty of obtaining suitable sample trees from fellings in the plot and surround, measurement of standing sample trees is recommended whenever practicable.

Measurement of standing sample trees has long been practised in European research work (*8*, p. 237). Appliances and methods for use in India are under examination at present.

Photo. H. G. Champion.

Felling and measuring sample trees in Sample Plot 48, Chakrata division, United Provinces, in *Cedrus Deodara* : Quality 1·9 II, age 92 years, crop height 103 ft., crop diameter 18·8 ins.

Opposite page 121.

(48) Three to five of the sample trees of somewhat above the mean diameter should be selected for height analysis to supply data concerning the past growth of the plot not otherwise obtainable. *See* Rule 60 below.

(49) Where difficulty is experienced in getting enough good sample trees of the larger sizes, typical standing trees of the main crop should be selected for additional height measurements. *See* Rule 61 below.

(50) A separate set of sample trees should be selected for a subsidiary species when it comprises more than 20 per cent. of the total number of trees, and contributes a significant part of the main canopy. In the case of mixed crops in which more than one species makes an important contribution to the main canopy, a full set of sample trees is required for each such species.

(51) If more than 12 trees are felled as thinnings, some of them should be measured as sample trees for the thinnings as described under Rule 63 below, or all may be so measured.

(52) If the volume of the understory is required, a separate set of sample trees should be measured for it. (This is not usually called for).

(*m*) *Measurements of sample trees.* See *Plate IX.*

(53) Standard measurements in πr^2 units as listed under General Rule 23, p. 10, should be taken on all sample trees.

(54) Branch smallwood should only be measured for species other than *sal*, teak, deodar, *chir*, and blue pine. Stem smallwood should always be measured.

(55) Measurements of sample trees should be recorded in Sample Plot Form No. 7.

(56) Where well established local standards of conversion and utilisation exist, the volume of sample trees should also be measured on these standards (cf. Rule 24, p. 11).

(57) It is useful to record the average length of the green crown and crown width as reflecting the density of the crop. Crown length is measured from the tip to a point midway between the lowest branch with green leaves, and the lowest point at which the crown is developed on all side of the bole.

Crown width may be measured after felling as the maximum spread of the branches on the ground excluding any which are clearly exceptionally long. As the point of maximum spread will often be at different heights on the two sides of the tree, each side should be measured separately.

(58) It is useful to record the diameter under bark at the point midway between breast height and the top of the tree, to permit of the calculation of form quotient (cf. p. 14).

This measurement should be substituted for the measurements at half total height for *sal*, teak, deodar, *chir* and blue pine, but as an extra measurement for all other species.

(59) The age of sample trees should be determined as under General Rules 16—19, p. 10.

(60) Stem analysis for height of the trees selected under Rule 49 consists in cross cutting at intervals of 10′ from ground level and counting rings at each section (so

that by subtraction from the total age, the age to the height of each section is known). This step often brings extra reliability to the routine stump ring counting.

(61) The height of the standing trees selected under Rule 49 above should be measured, but it is important to take the height of some of the sample trees before fellings using the same instrument, as a check on this work, all measurements being duly noted on the record. *See* Appendix X, p. 253.

(*n*) *Measurement of thinnings.*

(62) Standard measurements should be recorded for all trees felled as thinnings if they do not exceed 12 in number, with the proviso of Rule 51 above.

(63) If more than 12 trees are felled, eight or more should be selected as typical and measured as sample trees for thinnings only, apart from any already selected as sample trees for the main crop.

Trees accepted as samples for the main crop will often not be suitable as samples for the thinning, particularly with light thinnings.

(64) Where it is considered that statistical data for the first thinning are of small relative value as the operation only consists in removing material which would in a fully worked forest have been removed long before, or in clearing up the plot to facilitate work, only a record of diameters in 1″ classes need be made.

The local practice of omitting all measurements on such first thinning should be discontinued.

The most general practice abroad is to take complete measurement of all trees removed in thinnings. This is particularly desirable for the larger diameter classes, of which numbers will usually be small.

In the case of young crops including coppice, the number of stems removed may be too large for individual measurement but as very few measurements are required on each, it is not difficult to select and measure a series of them as samples for the thinning only.

(65) Where smallwood and fuel are of importance, the total stacked volume removed in thinning should also be measured and recorded in conformity with local practice, and a conversion factor for stacked to solid volume determined if not available (cf. p. 37).

(iv) Field Records.

(*a*) *Situation Map, Sample Plot Form 1.*

(66) A map on a scale 1m.=4″ should be prepared showing the situation of the plot with regard to the nearest road or path and rest house or camp. The main topographical features should be indicated; also the compartment boundaries, and any neighbouring sample plots.

The diagram for recording the dimensions of the plot, Rule 15, is inset on this map or on that referred to in Rule 67.

(b) *Plot Chart, Experiment Plot Form 5.*

(67) A detailed map shewing the position of the trees should be prepared on a scale 1″=20′. Methods are described in Appendix II (p. 141).

If it is desired to record any detailed topography (e.g., in connection with some entry on Sample Plot Form 2) this may be shewn on this Plot Chart, or Experimental Plot Form 2 may be utilised, being expressly designed for large scale survey.

(c) *Description of the plot, Sample Plot Form 2.*

(68) The following points should be given attention in filling this important form.

Entry 3.—*Area* is not required to be recorded in the field.

Entry 4.—*Situation* should be noted as regards the forest block and compartment, the nearest road or path, and rest house or camp.

Entry 6.—Under *Climate* should be recorded (i) the annual rainfall and its distribution, (ii) winter conditions, and (iii) hot weather conditions.

Entry 9.—*Type of forest* should not be confused with condition (Entry 16).

It is hoped to arrive at a standardised list of types of forest for India. When this is available, Entry 9 should consist of the appropriate standard type from this list, and any further remarks necessary to bring out special peculiarities or intermediate condition between two types.

Entry 10.—*Age* is only filled in for plantations of known date of origin.

Entry 16 (a).—Under *condition of overwood* should be recorded notes on the density and uniformity of stocking, appearance as regards quality of bole, general healthiness, etc.

Entry 16 (c).—Description of the weedgrowth should be adequate without becoming profuse. Standard abbreviations (*6*, p. 92) for frequency should be used: *va*=very abundant, *a*=abundant, *f*=frequent, *o*=occasional, *r*=rare, *vr*=very rare. A prefix *l* may be used to indicate that the frequency is local only, but this will rarely be required in sample plots. The relative abundance of grass and herbage should be mentioned, as well as the shrubs.

Entry 19.—*Remarks.* Here it should be noted whether the plot is much grazed, fire damaged, etc.

(d) *Diameter measurement, Sample Plot Form 3.*

(69) The following points should be noted in filling in Sample Plot Form 3. [As noted under Rule 40, Form 8 may be used in the first place if found more convenient.]

Main crop and subsidiary crop should be recorded on separate forms. *See* Rules 40—42, p. 119.

Height of cross mark and two diameters should be recorded for every tree.

Trees or stems with a common root system should be bracketted together.

The month as well as the year of measurement should be recorded (Entries such as 1927-28 should *not* be made).

(e) Measurement of sample trees. Sample Plot Form 7.

(70) The following points should be noted in filling Sample Plot Form 7. *See* Rules 53—61 above (p. 121).

No entry should be made in the space for age, but the number of rings and height of stump (measured from ground level on up hill side) should be noted just below it.

Height should be recorded to the nearest whole foot only, but length of shoot since last measurement is required to the first place of decimals in feet at remeasurement only. *See* Rule 76 below.

All pairs of diameters should be recorded as taken, their averages being struck only when computing later.

For volume measurements of timber or smallwood, entries for the stem should be completed first, followed by those for branches under a manuscript heading " Branch."

(f) Classification of diameters. Sample Plot Form 11.

(71) Classification by 1″ diameter classes will usually be done provisionally in the field to determine roughly the grouping for computation, and hence the approximate limiting diameters for which sample trees must be found.

(v) Field work for remeasurement of sample plots.

A. Full Remeasurement.

(73) Full remeasurement of plots should be done at 10-year intervals, except that full measurements will always be made when a thinning is done (*vide* Rule 27, p. 117).

(74) Remeasurements should be done as far as possible in the season of vegetative rest.

(75) All tree measurements prescribed for the first measurement should be taken at a full remeasurement and crown classes should be assessed anew.

When recallipering a plot, watch should be kept for trees shewing unusually high or low increment and these should be rechecked.

Diameter measurements of trees marked for thinnings are recorded in the right hand column of the original Form 3.

(76) For trees with annual rings, the length of the leading shoot put on since the date of the last measurement should be found by cutting off the top in short sections till it shews a number of rings equal to the number of years which have elapsed. It should be recorded in feet, correct to one place of decimals, from the beginning of the growth of that year.

(77) The cross marks and numbers should be repainted. No new trees should be cross marked or numbered except in the case of a plot hitherto unnumbered.

(78) The boundary trenches and corner posts should be repaired as required.

(79) The sides and diagonals of the plot should be remeasured by way of check.

B. Interim Remeasurement.

(80) If after a 5-year interval, a full remeasurement is not due, an *interim* should be made recording—

(i) Diameters of all standing trees.

(ii) Height of selected standing trees.

The above Rules 77 and 78 will also be followed.

(vi) COMPUTATIONS FOR FIRST MEASUREMENT.

The procedure which has been accepted for computation of the field data from sample plots is the Height and Form Factor Curve method. It was adapted from Schwappach's procedure in use at the Prussian Forest Research Institute by S. H. Howard (*9*) to meet Indian requirements, and was accepted by the Silvicultural Conference of 1918, (*10*, p. 3) being also approved by the Board of Forestry in 1919 (*11*, p. 37). Some details have been further modified, (*7*, p. 147 and p. 148), but no important part has been changed.

The most significant departure from Schwappach's method is the differentiation of timber and smallwood with an arbitrary dividing line at 8″ diameter over bark, particularly in that a separate form factor is calculated for each. It is believed that this was primarily introduced to meet the wishes of territorial officers who felt that in India, wood under 8″ diameter was and would always remain of relatively trifling importance. From the theoretical point of view, this step is questionable.

The only other criticism calling for mention concerns the question of crop height. It is pointed out that the average crop height as now calculated is only a mathematical conception impossible to visualise, that the height of the top group depends on the limits of the group, themselves often dependent on availability of sample trees, and that the average height of the dominant trees should be determined and used. As however, this matter does not necessarily affect the accuracy of the crop volume calculations, and is more closely connected with yield tables, it is dealt with under that head on p. 236.

Alternative methods of determining the volume of the crop on sample plots are the Volume Curve and Form Quotient methods. The Height and Form factor method is preferred to the volume method because the analysis of volume into two of its factors gives greater chances of detecting and reducing errors, and so should give greater accuracy. The Form Quotient method has not been tried out in India.

(A) Area of Plot.

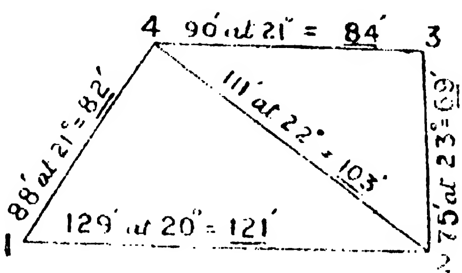
(1) The area of the plot is calculated from the field measurements of the sides and diagonals and their slopes, by reducing all lengths to their horizontal projections, and computing the area of the triangular portions. The field measurements are shewn on a small diagram inset on the Situation Map, Sample Plot Form 1, or the Plot Chart, Experimental Plot Form 5. See Field Rules 13—15, p. 115.

The slide rule will be found of very great assistance for rapid computation of plot area.

First, for any side a at a slope of $0°$, read *sin* $(90°—\theta°)$, and with one setting of the slide, read the horizontal projection, a *sin* $(90°—\theta°)$, and note it on the diagram. Repeat this operation for all sides of all the triangles. Thus for side 4—3, sin $(90°—21°)$ = Sin $69°$ = ·9336.

$$90' \times \cdot 9336 = 84'.$$

The areas of the triangles are then obtained by using the formula, *Area* $= \sqrt{s\,(s-a)\,(s-b)\,(s-c)}$, s being half the sum of the sides, a, b, c. As the result will be in square feet, it is divided by 43,560 to give acres. There is need for care with regard to the position of the decimal points, particularly before extracting square roots.



	I	II
a	84	82
b	69	121
c	103	103
2s	256	306
s	128	153
s—a	44	71
s—b	59	32
s—c	25	50

$$\sqrt{\text{Product}} = \sqrt{128 \times 44 \times 59 \times 25} + \sqrt{153 \times 71 \times 32 \times 50}$$

$$= 2882{\cdot}2 \qquad + \qquad 4169{\cdot}0$$

$$\frac{\sqrt{\text{Product}}}{43560} \qquad = 7051{\cdot}2 \text{ square feet.}$$

$$= \quad 0{\cdot}162 \text{ acre.}$$

(*B*) *Sample Tree Calculations.* (*Sample Plot Forms 7 and 4.*)

(2) The following computations are made and noted on Form 7.

(*a*) All pairs of diameters are averaged to one decimal place.

For diameters other than d. b. h., 0·05 is taken alternatively as *nil* and 0·1.

(*b*) The sectional areas required are read from tables (cf. p. 2,7) to 4 decimal places.

(*c*) The volumes of cylinders required are obtained by multiplying sectional areas by lengths of sections; they are calculated correct to 4 decimal places.

(*d*) Volumes of timber and smallwood sections are separately totalled.

(*e*) Form factors for timber and smallwood are obtained by dividing the volume of each by the volume (already entered in the Remarks column) of the cylinder erected on the breast height basal area of the tree up to its total height.

(*f*) Total age is determined by adding to the recorded number of rings on the stumps, the allowance corresponding to the stump height as standardised for the species.

(*g*) Bark per cent. is obtained by multiplying the difference between sectional area over bark and under bark at half-height by 100, and dividing by sectional area over bark at the same height.

(*h*) Bark thickness at 4′ 6″ is half the difference between the average diameters over and under bark.

(3) A summary is made on Form 4 by copying the entries required directly from the Forms 7 of the several sample trees.

(*C*) *Age Curve.*

(4) The points for age from the sample trees are plotted against diameter on a scale suitable for reading age to the nearest year, conveniently 1″=10 years and 2″ diameter. Curve I, following p. 169.

(5) The best freehand curve is fitted over the points and revised after rejection of such points, if any, as are considered abnormal.

The curve for plantations will usually be slightly curved for the lower diameters reaching a constant value for the higher. In natural regeneration this uniformity does not prevail, and the curve may be of various forms.

The curve cannot be constructed for species without satisfactory annual rings of growth. For determination of crop age with such species see sub-chapter ix below, p. 135.

(*D*) *Height curve.*

(6) The values from the sample trees for average d. b. h. and total height are plotted on squared paper on a scale adequate to give readings to the nearest ½ foot (usually ½″ to each 1″ diameter and 1″ to 10′ of height).

(7) Any additional heights measured under Field Rules 48 and 49 are similarly plotted using distinguishing symbols.

(8) The best fitting freehand curve is then drawn over the points—Curve II.

It should be remembered that this curve has no connection with that representing change in *crop* height with age, and follows quite a different course: when the crop is truly even-aged, there can obviously be no question of correlation of height or diameter with age. The curve (often nearly straight) usually cannot be easily extra-polated to pass through the origin.

Some points may have to be considered for rejection (cf. p. 6). The value of pairs of points and the importance of having a suitably distributed set of points particularly for the larger diameters, will be apparent.

(*E*) *Form factor Curves.*

(9) The form factors of the sample trees recorded on Form 4 for Stem timber, and Stem smallwood are plotted against diameter. Total smallwood points are not plotted direct; instead, the values for branch smallwood are plotted, measuring not from the plotted stem smallwood point of the tree in question, but from the corresponding point on the stem smallwood curve constructed under Step 10 below.

If there is any branch timber, total timber form factors are obtained by the same method as total smallwood form factors.

With species for which branch smallwood has been standardised, the corresponding points and curves are not required.

The sample plot of Example 35 happens to have no branch smallwood.

(10) Best fitting freehand curves are then drawn over the 3 or 4 sets of points. Trees rejected for height are given less weight for form factor, and other points may have to be rejected, since a satisfactory height value does not necessarily imply satisfactory form.

The timber curves must originate from the neighbourhood of 7½" d. b. h., and the smallwood and total stemwood curves from the neighbourhood of 1½" d. b. h. The timber curves normally rise at first rather rapidly and then flatten out—only in exceptional cases should any maximum be apparent.

The smallwood curves normally rise very rapidly to a maximum at about 4" to 6" according to species, and then fall not quite so steeply to a low figure, after which they tend to remain nearly constant. They cut the timber curve between 9" and 11".

The total smallwood curve will obviously be coincident with the stem smallwood curve until branches over 2" diameter are formed, usually at a diameter of about 11"—14" for conifers and 6"—9" for broad leaved trees, and then slowly diverges from it.

The curved values for stem timber and stem smallwood form factors can be totalled and checked against the total stemwood form factor curve, any significant difference being reduced by mutual adjustment of the curves. It has been found in practice, however that little or nothing is to be gained by this procedure.

(*F*) *Classification and grouping.*

(11) The main crop diameters are classified by 1" diameter classes, the two diameters for each tree being treated as though independent. Sample Plot Form 11, p. 211.

Note that in the 13" class, for example, are included all diameters between 12·5" and 13·4" inclusive.

(12) The diameters are then grouped with the help of the table and instructions on p. 143—5.

The differences in accuracy between the many methods brought forward are all small and probably within the errors of sampling and measurement. The method given here is followed as it keeps together at successive remeasurements the same number per acre of the largest diameters, so that the history of say the best 50 stems per acre is kept in view throughout: even when the group of 50 is subdivided, it is only factorised and so can be simply restored by totalling.

The details of the method itself, its interpretation, and its application in India have varied considerably. The acreage basis appears to have dropped out in the previous Statistical Code and as it is the main justification for the method, it has been restored. The ruling of an arbitrary line after the 8" class also confuses the issue, and the procedure here adopted attempts to adjust this to some extent. Inadequacy of sample trees sometimes results in enforced departure from this standard procedure, when the mean diameters of the groups fall beyond the limits between which the curves can be drawn from the sample trees.

It will sometimes happen that a single diameter class will be subdivided into more than two groups, so that the same values for group diameter, etc., are repeated. No inaccuracy is however introduced and so little extra work that it is not worth varying the procedure for such cases.

(13) The subsidiary crop is similarly dealt with separately from the main crop.

(G) *Calculated Mean Trees.* (*Form 5, p. 160.*)

(14) The basal area in each diameter class is looked up in the tables and recorded (Col. 3).

(15) The total basal area of each group is obtained by totalling the areas in the included diameter classes (Col. 5).

(16) The mean basal area for the group is obtained by dividing the total by the number of diameters (Col. 6).

(17) The corresponding diameter is extracted from the tables (Col. 7).

(18) The height corresponding to this diameter is read from the Height curve to the nearest whole foot, and recorded in Col. 8.

(19) The form factors for the same diameter are read from the form factor curves to 3 places of decimals, and recorded in Cols. 9—11.

(H) *Volume* (*Form 5, p. 160*).

(20) The volumes are calculated to 2 places of decimals as the product of basal area, height and form factor; thus, Timber volume=Col. 5×Col. 8×Col. 9; $176{\cdot}26=7{\cdot}5324\times75\times{\cdot}312$.

(J) *Crop Data* (*Form 5*).

(21) The remaining entries on Form 5 are completed as follows :—

(*a*) ***Range of diameters.***—From Col. 1.

(*b*) ***Number of diameters.***—Total of Col. 4.

(*c*) ***Total basal area.***—Total of Col. 5.

(*d*) ***Average basal area.***—Total basal area divided by number of diameters. Col. 6.

(*e*) ***Average diameter.***—From average basal area with help of tables. Col. 7.

(*f*) ***Crop height.***—By applying Lorey's formula to the basal areas (s_1, s_2, s_3, etc.,) and heights (h_1, h_2, h_3, etc.) of the groups. Col. 8

$$H = \frac{s_1h_1 + s_2h_2 + s_3h_3 + \dots}{s_1 + s_2 + s_3 + \dots}$$

(g) *Total volumes.*—Totals of Cols. 12, 13, 14.

(h) *Crop form factors.*—By dividing the total volumes by the crop height and total basal area. Cols. 9,10,11.

(K) *Crop figures per acre* (*Form 6, p. 18*).

(22) Form 6* is finally filled in as follows.

(a) Heights, form factors and diameters are copied direct from Form 5.

(b) Number of stems, basal areas (1 decimal place) and volumes (nearest cubic foot) are derived from the corresponding entries in Form 5 divided by *twice* the area of the plot (to 3 decimal places of an acre).

Two diameters have been taken for each tree, doubling the number of trees. If branch smallwood volume has not been calculated (*vide* Rule 54), no entry will be made in Cols. 16 and 17. The percentage relationship of branch smallwood to stem should also be recorded under the branch smallwood volume entry if this latter has been made.

(c) The age of the crop is read against the average crop diameter from the Age curve.

(L) *Mixed Crops Procedure.*

(23) Trees of a subsidiary species for which separate sample trees have been measured, are dealt with separately throughout the computations (cf. Field Rule 50), and similarly for the several species in a mixed plot. In other cases, trees of subsidiary species are included with the main species throughout the calculations.

(vii) Computations at remeasurement for trees with annual rings. (Back check method.)

Errors in sample plot measurement are primarily connected with the selection of sample trees. Increment is determined as the difference between the volumes calculated at the two measurements with the aid of the sample trees and big percentage errors in this difference will commonly occur—and indeed are to be expected—unless the errors of sampling happen to be similar in extent and direction. To go some way towards getting over this difficulty, a procedure has been adopted by which both sets of sample trees are combined, and the errors to some extent distributed.

The method is to utilise the available data to bring the old sample tree figures up to date by adding the increments they should have put on in diameter and height (and theoretically in form factor also), had they been allowed to grow on till the remeasurement. The double set of sample trees is then utilised for drawing the

* The heading for column 16 on Form 6 requires to be altered to read " Branch Smallwood " instead of " Total ".

curves for both measurements as explained in the following sections and exemplified on pp. 158—183, and Curves VI to VIII.

Objection may be raised against the method on the ground that the procedure of adding increment to sample trees of the previous measurement does not render them acceptable as sample trees for the crop at remeasurement. For a given class, the sample tree increases not only by growth in diameter and height, but also by the elimination of weaker stems removed in thinnings, and so the points on the height curve representing heights of "brought up" trees fall below those for the sample trees at remeasurement. So if the choice of sample trees is correct for both the measurements, back check means loss rather than gain in accuracy of results.

Again if incorrect choice of sample trees is assumed for both the measurements, the errors will cancel or average out only if they are normally distributed as between the two sets of trees—an assumption which often cannot be justified considering that sampling is done by different persons, under different conditions and at different times.

Lastly, admitting that improvement in accuracy results from the method in cases in which positive and negative errors affecting the choice of sample trees can be assumed equally frequent, the utility of the method may still be open to question on practical grounds.

It should be noted that the difference between the two plot volumes (i.e., the increment) is not used in any of the later steps of yield table compilation as here described, but individual plot values for each quality are averaged by decades. The errors involved are thus evened out, provided the number of measurements is adequate. It is in increasing the number of measurements by laying out new plots and making remeasurements and so filling the gaps and deficiencies in the existing plot series, that the true solution of the difficulty lies; the back check method will then become unnecessary.

(*A*) *Area.*

(24) It is advisable to recalculate the area by way of check. If the discrepancy of the two calculations exceeds 2 per cent., the figures affected in Form 6 should be corrected: this need not be done for smaller differences.

(*B*) *Sample Tree Calculations.*

(25) These are made exactly as at first measurement (p. 126).

(*C*) *Diameter Increment Curve.*

(26) The steps in the constructions of this curve, Curve IV, are the following:—

(*a*) Classify and group the new main crop diameters as usual (p. 213).

(*b*) Classify the diameters which the trees still standing had at the previous measurement (p. 215).

(*c*) Group the previous measurement diameters of the trees now forming the main crop into groups of the same number of diameters as for the remeasurement (p. 215).

(*d*) Classify and group the new subsidiary crop diameters as usual (p. 214).

(*e*) Classify and group the previous measurement diameters of the trees forming the new subsidiary crop (previously part of the main crop) into groups of the same number of diameters as for the remeasurement, i.e., as under (*d*) above (p. 216).

(*f*) Fill in Cols. 1—5 of two Forms 5 for the two sets of measurements of the trees forming the main crop at remeasurement (1925 on p. 162, 1920 on p. 166) another for the earlier measurement of the trees transferred to subsidiary crop at remeasurement (p. 168) and a fourth for the subsidiary crop at remeasurement (p. 164).

The calculations of the two parts of the previous main crop are done separately and then combined, as shewn in the example.

(*g*) To the Totals column for the previous measurement, add in the total number of diameters and total basal area from the Form 5 for earlier measurements of the new subsidiary crop, thus obtaining main crop figures for the previous measurement (p. 166).

(*h*) Fill in Cols. 6 and 7 in all Forms in the usual way, except in the Totals line of earlier measurements of the new subsidiary and main crops, where entries are not required (p. 166, 168).

(*j*) Average diameter for each group at the two measurements is available from the two Forms for new main crop only, and the differences give the increments during the period between the measurements.

It may be noted that the increments so deduced do not refer to identical sets of trees at the two measurements. The trees removed as thinnings at remeasurement will show a smaller increment, and such trees would mostly not be suitable as sample trees; they are therefore not utilised for the increment curve.

(*k*) Plot these values for increment against the diameter at previous measurement, and fit the best freehand curve over the points. (This usually gives a straight line rising slowly with diameter.) Curve IV.

(*l*) Bring the old sample trees up to date by adding to their diameters the increments corresponding to the latter as read from this curve. See table with Curve IV.

(*D*) *Height Increment Curve.*

(27) This curve, Curve V, is obtained thus :—

(*a*) Plot the height increment of the new sample trees since last measurement from Col. 5 of Form 4 against diameter, and fit the best freehand curve.

It should be noted that, unlike diameter increment, height increment is plotted over the remeasurement diameter, not over the previous diameter.

(*b*) Read to the nearest foot from this curve the height increments since the previous measurement for the diameters of the old sample trees brought up to date under Step 26 (*l*) above, and add them to the measured heights then recorded, thus bringing height also up to date. See table with Curve IV.

(*E*) *Height Curve.*

(28) Plot together the heights against diameters for the new sample trees and the old ones thus brought up to date (using different symbols for the two sets of

Plate X.

Photo H. G. Champion.

Sample Plot 10, Saranda division, Bihar and Orissa, in *Shorea robusta*: Quality I, age 134 years, crop height 119 ft., crop diameter 21·8 ins. This plot is overmature but should be maintained for its value in determining the extent of falling off of increment. It is intended to include it in a "nature" reserve of exceptionally fine big *sal*.

Opposite page 133.

points for the sake of clearness), and fit the best freehand curve. This gives the height curve for the main crop at remeasurement, Curve VI-A.

(29) To construct a revised height curve for the previous measurement, the height increment during the period is read from the curve for the average diameter of each main crop group at remeasurement, and by subtraction from the average height for the group already entered on Form 5, the corresponding height at the commencement of the period is obtained. The average diameters at the previous measurement for the same groups is also already available from the corresponding Form 5, p. 166 ; see table with Curve IV. The reduced heights are then plotted against the group diameters on the same paper, and a height curve is drawn for the previous measurement, Curve VI B.*

Sometimes the groups for the subsidiary crop at remeasurement and the corresponding portion of the main crop at the previous measurement may also be utilised.

This curve should be of similar form to that first drawn, and in the case of immature crops will usually be a little below it, i.e., trees of a given diameter *d* will have a rather greater height at age *a*+5 (or *a* + 10) than at age *a*.

In case of older crops, the two curves may tend to meet at the larger diameters ; errors in the selection of sample trees may obscure this tendency. Crossing of the curves may result from exceptionally larger diameter increment, or low height increment, usually the latter.

(30) This curve should be checked as shewn in Step 35 below, and revised if necessary.

(F) Form factor Curves.

(31) These curves are drawn from the data of both sets of sample trees together; Curve VII.

It has been found that the change in form factor (particularly for the important larger trees) during a 5 or 10-year period is smaller than the ordinary errors of measurement. If, however, the form factor points for remeasurement show an appreciable systematic deviation from those of the earlier measurement, separate curves may be drawn and used in computations. Such systematic deviation need not indicate error in the choice of trees, and may be expected even with perfect sampling.

(G) Age.

(32) A new Age curve, Curve VIII, is constructed as before, except that the previous sample trees are also plotted after having been brought up to date by the addition of the known number of years to their age and the diameter increment as done in the table with Curve IV. Crop age is then read against the average diameter. A discrepancy as compared with age obtained by adding the number of years in the period since last measurement to the age then determined, is usual. If mutual adjustment of the curves can be made to remove this disagreement, this adjustment should be made, the age recorded at the previous measurements being revised if necessary. If this is not possible with due regard to the points, one value should be accepted, and the other brought into agreement with it on Form 6.

(H) Volume Calculations.

(33) Form 5 for main and subsidiary crops at remeasurement (1925) has been filled up as far as Col. 7. The rest of the data are filled in with the help of the curves exactly as for first measurement.

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* Owing to a slip, the two 1925 sample trees, $d=11{\cdot}6$, have been plotted at $h=67{\cdot}5$ instead of $66{\cdot}5$, and the point for the sample tree of $7{\cdot}6''d$ and $53'h$ on the 1920 back-check curve does not appear.

(34) Form 5 for the previous measurement (1920) is similarly completed, using the new curves prepared for it, subject to the check described in Step 35 below.

(35) Height increment during the period for the average main crop diameter at remeasurement is read from the height increment curve, and is deducted from the average crop height giving a figure for crop height at the previous measurement for the trees still standing at remeasurement. An independent value for this can be obtained by the application of Lorey's formula to these trees, and the two figures should agree within a foot; if they do not agree, the height curves for the previous measurement must be revised till they do. This calculated value should be entered in square brackets in the summation line for Col. 8 of Form 5, as done on p. 166.

(J) *Crop figures per acre.* (Form 6).

(36) Form 6 is then filled in.

(*a*) Figures for the remeasurement are filled in exactly as at first measurement (Step 22).

(*b*) Figures for the main crop at previous measurement are corrected in red ink to those now obtained by recalculation.

(*c*) Figures for the subsidiary crop at previous measurement remain unchanged.

(K) *Crop Increment Data* (Form 6).

(37) The increment columns 30—33 are completed as follows :—

(*a*) Periodic basal area increment (Col. 30) is obtained by subtracting the main crop basal area at the previous measurement (Col. 13) from the new total crop basal area (Col. 28).

(*b*) Periodic mean basal area increment (Col. 32) is obtained by dividing the figure just entered for the period, by the number of years in the period. In Ex. 35, this is taken as 5 though $4\frac{1}{2}$ would probably be more correct.

(*c*) Periodic stem timber increment (Col. 31) is obtained in the same way as Col. 30, by subtracting Col. 14 at previous measurement from the new volume in Col. 29.

(*d*) Periodic mean increment for the stem timber (Col. 33) is similarly obtained by dividing Col. 31 by the number of years in the period.

(viii) Measurement of Clear-felled Plots.

(A) *Felling consequent on regeneration operations or deforestation.*

(*a*) When the forest in which a sample plot is situated comes under regeneration, it should first be considered whether the plot and its surround should not be excluded from the fellings for collection of growth statistics for a further period of years, or as a reserve for its aesthetic and scientific value (see Plate X and (7) Proc. Silv. Conf., 1929, Item 22), or for other purposes.

(*b*) If it is decided to abandon a plot to permit of regeneration operations or for any other purpose, the opportunity should always be taken for measuring all trees, and thus providing an exact knowledge of the final yield of the plot and a valuable check on the sample tree method in its local application.

(*c*) In such cases, sample trees should be selected in the usual way before the felling, all trees in the plot being now available for the purpose, and they should be measured up, and the computations for crop volume completed in the usual way. The rest of the trees should also be measured up in the same way as sample trees.

(*d*) If it is essential to leave a few of the trees standing as seed trees, the height of each should be measured with care, and form factor taken as the same as that of the felled tree which is estimated as most similar to it, and if they are felled within 10 years, the extra measurement of height increment required for the back-check method should be collected to allow of the reduction of the dimensions recorded on felling to what they would have been when the rest of the crop was felled.

(*e*) In the case of coppice crops, clear-felling will be the usual final step in the collection of data for the plot. The data to be collected will depend on the objects of management and of the investigation, but total volume should always be directly measured. All trees should be callipered before felling. The height should be measured of a liberal number of sample trees selected in the ordinary way, or, when numbers are not too large, may be measured on every stem. Volume will not usually be determined on the sample tree method, but either by :—

1. Measuring up every stem on standard rules, *or*
2. Measuring stacked volume of the whole outturn and applying a conversion factor for solid volume, *or*
3. Sorting the material by classes (notably poles), and determining the average solid volume per unit of each class (including stacked cubic feet for stacked fuel, etc.).

(*B*) *Fellings for the special purpose of collection of data.*

In the case of short rotation coppice, and less commonly of seedling forest of natural or artificial origin, it may be possible to select plots in crops of known age, clear-fell them, and measure up the final yield on the felled material without resort to the sample tree method. The advantages are the rapidity with which the required data can be collected, and the elimination of the personal factors and difficulties of finding suitable sample trees with the sample tree method : full demarcation, numbering of trees and maintenance of plots is also avoided. Somewhat smaller plots are acceptable under this method, but $\frac{1}{5}$th acre should be the minimum size.

The field work is the same as described under the last head above.

(ix) Computation Procedure for trees without annual rings.

The number of species concerned is not large, as absence of rings usually implies climatic conditions under which the forests are of mixed species, so that pure even-

aged crops are unusual. *Shorea* was formerly included, but it was later decided that though the counts were none too reliable, they were at least serviceable. Of the oaks, *Quercus dilatata* at least has discernible rings and *Quercus incana* is at the moment the only species without rings for which an indirect determination of age is called for with any urgency.

(A) Age.

Method I.—An estimate of the age of a crop (or a diameter class in a crop) can be determined without reference to any other plot, provided at least two remeasurements have been made, by calculations based on the growth per cents. during the two periods.

The calculations are based on the assumption that growth per cent. p is a hyperbolic function of diameter, so that $p = \frac{K\dagger}{d^s}$ where K is a constant, d is the diameter and s an exponent which can be evaluated as follows :-

$$\frac{1}{d}\frac{\delta d}{\delta t} = p \text{ (by definition).}$$

$$\frac{1}{d}\frac{\delta d}{\delta t} = \frac{K}{d^s} \text{ (by substitution for p).}$$

$$d^{s-1}.\delta d = K\delta t.$$

$$\frac{d^s}{s} = Kt + c \text{ (by integration, c being an integration constant).}$$

$$\frac{d^s}{s} = Kt \text{ (The value of c being negligible, since when t = 0, d is also zero) : Equation (1).}$$

$$p_1\, d_1^s = p_2\, d_2^s = K \text{ (Where } p_1,\ p_2 \text{ are the growth per cents. during the two periods from the two initial diameters } d_1,\ d_2\text{) : Equation 2.}$$

$$t = \frac{1}{p.\ s.} \text{ (by substituting } pd^s \text{ for K in Equation (1) ; p is known from the original data) : Equation (3).}$$

$$s = \frac{\log p_2 - \log p_1}{\log d_1 - \log d_2} \text{ [taking logarithms in Equation (2)] : Equation 4.}$$

The method has been checked on six plots of known age of *Pinus longifolia* and *Cedrus Deodara*, and gave the age correctly within 4 years ; with 9 plots of *Quercus incana*, it gave values close to the best available estimates.

The actual computation is done as follows :—

(1) Calculate the average diameter d_3 of the top group of diameters for the plot, combining group 2 with it if group 1 has less than 20 diameters for the last (or third) measurement. Actually the diameters of all dominant and co-dominant trees can be utilised in the same way (*vide* Ex. 36, p. 137).

† The estimate of age derived from this equation may be improved by the addition of a constant, the value of which will vary slightly with different species.

(2) Calculate the average diameters d_2 and d_1 of the corresponding groups of the same number of diameters for measurement 2 and measurement 1.

(3) Express the increases d_1 to d_2 and d_2 to d_3 as percentages, p_1 and p_2.

If tables of logarithms to the base *e* are available, the calculation of p_1 and p_2 can be simplified.

$$P_1 = \frac{1}{d}\frac{\delta d}{\delta t} = \frac{\delta \log_e d}{\delta t.}$$

So to get p_1, take logarithms to base *e* of d_1 and d_2, subtract, and divide the difference by the number of years in the period.

(4) Substitute these values in Equation (4), obtaining a value for s.

(5) Solve Equation (3) for each of the values of p, obtaining values for *t* for the ages corresponding to d_1 and d_2.

The difference $t_2 - t_1$ should approximately equal the known interval between the measurements.

(6) Repeat for the second and third groups with not less than 20 diameters.

(7) Select the best value of t_1 remembering that the best result is to be expected from the first group.

Very often inaccuracy is introduced into the calculation of p by the fact that the period of remeasurement does not correspond to an exact number of growing seasons: if measurements have been taken during a growing season, an estimate of the actual number of growing seasons (fractional if necessary) which have elapsed, should be used.

When more than three measurements are available, they should all be combined and the value of s determined by the method of least squares, using the equations :—

$$\left.\begin{aligned} \Sigma\ y &= -s\,\Sigma\, x + \Sigma\, c \\ \Sigma\ xy &= -s\,\Sigma\, x^2 + c\,\Sigma\, x \end{aligned}\right\} \quad \text{Where } \begin{aligned} y &= \log p \\ x &= \log d \\ c &= \log k \end{aligned}$$

Ex. 36. The average diameter of dominant trees, S. P. 6, Naini Tal division, United Provinces, Quercus incana, *calculated for the three measurements made in 1911, 1916, and 1921, is 5·4", 6·0", and 6·6". Required the age of the plot.*

Average diameter, d.		$\log_e$ d	$\delta \log_e$ d	p.
5·4	—	1·68640	·10536	·02107
6·0	—	1·79176		
6·6	—	1·88707	·09531	·01906

$$s = \frac{\log \cdot 02107 - \log \cdot 01906}{\log 6{\cdot}0 - \log 5{\cdot}4}$$

$$= \frac{\cdot 04354}{\cdot 04576}$$

$$= \cdot 951$$

$$t = \text{Age in 1911} = \frac{1}{\cdot 02107 \times \cdot 951} = \frac{1}{\cdot 02}$$

$= 50$ years.

Ages of other plots worked by the same method are tabulated below :—

Sample Plot Number.	Initial year.	Best available estimate of age.	Calculated age.	Difference.
Pinus longifolia.				
West Almora 38	1916	16	12	—4
37	1916	17	18	+1
33	1916	23	26	+3
Lower Bashahr 13	1914	26	23	—3
Kaunli 1	1912	30	28	—2
Quercus incana.				
Ranikhet 19	1916	21	22	+1
20	1926	21	17	—4
21	1912	19	18	—1
22	1912	20	14	—6
23	1926	26	18	—8
24	1916	26	19	—7
Kaunli 2	1912	30	22	—8
Cedrus Deodara.				
Kulu 2	1914	48	50	+2

Method II.—An independent estimate of age can be obtained after one remeasurement from the combined data of a number of plots which can be taken to be approximately the same quality on any acceptable standard, provided they cover a fairly wide range of diameters, and the approximate age of any one of them can be estimated.

The method is based on the assumption that on one locality quality, the diameter increment of the bigger trees in a plot, i.e., those which have grown and are growing with relatively little interference from their neighbours, will be a function of the diameter. By combining the increments during the remeasurement interval for the trees in the same diameter classes of the several plots, taking x per acre in each, the relation of diameter at the two ends of the interval can be determined over the whole range of diameter. From this relation, it is simple to plot diameter against time, but the age of at least one plot is required to fix the zero point for time. Age is then read from this curve against the average diameter of the biggest x trees per acre in the plot.

Trials with ring forming species have given the best results working with 50 trees per acre. The average diameters of the biggest 50 trees *per acre* of the first measurement of the plot are written down by 1″ diameter classes, and against them the average diameter attained by the same trees at the second measurement. Each set is totalled and averaged for each diameter class. (The remeasurement interval

must be the same in all cases; if not, it must be proportionally adjusted). This is done for each plot accepted as of comparable quality class, and a general average diameter (D_{50}) determined for each. Second diameter is then plotted against initial diameter for each 1″ class and the best fitting freehand curve fitted over the points.

The same procedure has been utilised for data from increment-borings, see Ex. 33, p. 99, and the accompanying curves.

It is probably best to draw the curve for each plot separately first and then run a general curve over the several plot curves.

Then, starting from the lowest acceptable diameter, d_0, on this curve, the diameter d_1 reached after the remeasurement interval is read off; next d_2, reached in the same number of years after d_1, and so on, for the whole length of the curve. These values d_0, d_1, d_2....are now plotted against time, each pair being separated by the same time interval, and a smooth curve drawn. The zero for time is then shifted so that the average diameter of the 50 biggest trees per acre on the plot of known age corresponds to that age, and the curve is extrapolated to zero. The age of all other plots is then read off against the already determined average diameters (D_{50}).

The application to the individual plots will evidently depend largely for its accuracy on the range of quality included in the plots combined. The narrower this range the better, and so a group of closely adjacent plots easily compared is preferable if it can be obtained; on the other hand, it is preferable that any mistake in placing zero age should be the same for all plots, and not different for each local set.

A method based on the same considerations as used in this section, has been suggested for testing the comparability of quality class as between the several plots, but the opportunity has hitherto not occurred for applying it.

Ex. 37.—The age of Nainital division Sample Plot 6 of Quercus incana *as deduced on this method is 48 years, which may be compared with the result with Method I, given in Ex. 36, i.e., 50 years.*

The ages of some of the plots of *Pinus longifolia* referred to in Ex. 36, give the following values on this method:

Plot No.		Best available estimate of age.	Age on Method I.	Age on Method II.
West Almora . .	38	16	12	15
	37	17	18	17
	33	23	26	26

(X) Register of Sample Plots.

In order to facilitate check of the number of plots laid out and maintained in each division and the years in which they are due for remeasurement, a record is maintained on a Form giving this information. An example is given below. The last column is filled in in pencil.

UNITED PROVINCES.

Chakrata Division.

Date of establishment.	By whom laid out.	Species.	Locality.	Number of Plot.	DATE OF SUBSEQUENT MEASUREMENTS. 2nd.	3rd.	4th.	Date for next measurement.
October 1912	F. R. I.	Cedrus Deodara	Mundali, Compt. 17	13	October 1917.	May 1922	May 1927	1932 Hot weather.
June 1915 .	Do. .	Do. .	Kanasar, Compt. 7.	18	May 1920	May 1925	..	1930 Hot weather.
Do. .	Do. .	Do. .	Kanasar, Compt. 10	19	Do. .	Do. .	..	Do.
Do. .	Do. .	Quercus semecarpifolia.	Deoban, Compt. 9.	20	Do. .	Do. .	..	Do.
June 1924 .	Provincial Staff.	Do. . .	Deoban, Compt. 6.	43	..	..	..	Do.
May 1928 .	F. R. I.	Pinus excelsa .	Kanasar, Compt. 7.	55	..	..	..	1933 May.
Do. .	Do. .	Do. . .	Do. .	56	..	..	..	Do.
Do. .	Do. .	Cedrus Deodara	Kanasar, Compt. 10.	58	..	..	..	Do.

APPENDIX II.

Preparation of the Plot Chart. (See Rule 67, p. 123.

I. Triangulation Method.

The method of *triangulating* with a tape by determining the distance of every tree from two previously fixed points starting with one corner post and any convenient point on the boundary line, is very simple and fairly quick for level or evenly sloping plots; it is however not suited to plots of irregular contour. As mistakes are easily made and carried on, it is essential to prepare the map at the same time and check the position allotted to a tree on the two measurements by another to a third fixed point at frequent intervals. The procedure is appended.

(1) Draw the outline of the plot (actual measurements) on squared paper on a scale 1″= 20′, with one of the sides along the ruling.

(2) Starting from one corner post and a convenient point on one of the boundary lines about 50′ distant, measure the distance from these two points of each conveniently situated tree, in straight lines, the ends of the tape being kept at a height of 4½′ above ground in all cases.

(3) Strike two arcs with radii equal to these two measurements from the two fixed points, their intersection giving the position of the tree, which is marked by its number.

(4) The triangles thus measured should not have any angle much exceeding 120° or less than 30°.

(5) All trees quite near the boundary line should be checked by their perpendicular distance from the line.

(6) On completion of the mapping of all the trees conveniently reached from the first two fixed points, one or both of the latter is changed for another corner or fixed point on the boundary, and the work continued.

(7) When more convenient, any tree already mapped may be used as one of the fixed points, provided its position is checked as in (8).

(8) A check is essential, particularly when the measurement is taken from one tree to another, to avoid carrying on an error which has been accidentally introduced. This is possible by taking an additional measurement to any previously fixed point, and should be applied to every tenth tree or so, significant discrepancies being eliminated before carrying on.

(9) If the central parts of the plot cannot be dealt with from the boundary, they are done from any convenient pair of trees already mapped, but the positions of these must be checked and fixed beyond question.

As a good alternative, a new base line may be run across the plot between fixed points on the periphery.

(10) Plotting on this method takes somewhat longer than Method II for a plot with relatively few trees per acre, but less time for denser plots.

(11) It is not necessary to record the actual measurements.

II. Optical Square Method.

The *optical square* has often been used in the past. Its merit is quickness, but the map obtained lacks in accuracy particularly as regards the relative positions of trees distant from the base line. Here, too, it is highly advisable to map the readings as they are taken. The procedure is appended.

(*a*) One of the longest sides of the plot is selected as base line, and a tape or chain stretched along it. On hilly ground, a line of maximum gradient should be used.

(*b*) Starting at one end of the base line with a flag at the other end to sight on to, the point is found for each tree in turn at which the perpendicular from it to the base line meets the latter, actual distances along the base line and horizontal distances from the tree being recorded for each. (The direction of the perpendiculars may

even be estimated by eye, difficult groups being checked (or dealt with originally) with the optical square, to give a rough provisional map if circumstances do not allow of anything better.)

(*c*) The base line should be extended if necessary at either end.

(*d*) The maximum distance from the base line to which trees should be measured is 30′.

(*e*) On completing one strip in this way, the base line tape is shifted to a new position parallel to the first and 60′ from it, and a new strip mapped, offsets being taken on both sides, and the procedure repeated till the whole plot is covered.

(*f*) The outline of the plot (horizontal projection) is mapped on a convenient scale on squared paper (Exp. Plot, Form 5), so that the first used base line follows the ruling. The positions of all trees are then plotted, the distances along the base line being first corrected to horizontality when the gradient exceeds 10°.

(*g*) As the relative positions mapped will be somewhat misleading, the several base lines should be drawn on the map; the offsets may also be dotted in, the length being noted against each if there is space to do this clearly.

(*h*) The tabulated field measurements should be recorded with the map on the file unless entered on the map itself.

(*j*) Plotting with the optical square usually takes about 1–2 hours per 100 trees, depending on the nature of the plot. Regular plantations may be mapped directly on squared paper, the assumption being made that the plants have been accurately spaced at the intended distances.

APPENDIX III.

Instructions for grouping trees in Sample Plots.

The total number of diameters per acre and the number per acre over 8″ in the plot should first be determined.

If the number of diameters over 8″ is less than 25 per acre, no differentiation should be made at this limit ; similarly for a small number below 8″.

The prescribed grouping for the total number of diameters is ascertained from the appended table and written across the page (see line B in the example below).

Below it is written the prescribed grouping for the diameters over 8″ only, in such a way that as far as possible the total number of diameters to the left of any vertical column is the same in each line (line C). The first group of 50 should not be subdivided in this operation.

For the diameters under 8″ (line D), the first group will take the number necessary to restore agreement between line B and line C for the sum of the bordering groups of timber and small-wood diameters. If, however, the first group under 8″ includes less trees than the last full group over 8″, the former should be combined with the following group. For subsidiary crop, the residual number of diameters over 8″ when less than half the previous group, should be combined with the latter ; see example on p. 214. These number per acre entries in line E should then be multiplied by the area of the plot in acres to give the actual numbers for the plot, line F. The total is then checked to give the correct total, as a slight discrepancy may be introduced in rounding off.

Ex. 38.

A. *Area of plot*	=0·162										
B. *Total number of diameters per acre.*	=1062=50	50	50	50	100	100	100	100	200	262.	
C. *Number of diameters 8″ and over.*	= 747=50	50	50	50	100	100	100	100	147.		
D. *Number of diameters under 8″.*	= 315=									53	262.
E. *Groups for one acre*	=1062=50	50	50	50	100	100	100	100	147	315.	
F. *Groups for plot of 0·162 acres.*	= 172= 8	8	8	8	16	16	16	16	25	51.	

Number of diameters per acre to be included in each group.

Number of diameters per acre.	Number of diameters per group.
Up to 124 . . .	25 25 rest.
126—198 . . .	50 50 rest.
200—248 . .	50 50 50 rest.
250—348 . . .	50 50 50 50 rest.
350—448 . . .	50 50 50 50 100 rest.
45—548 . . .	50 50 50 50 100 100 rest.
550—648 . . .	50 50 50 50 100 100 100 rest.
650—848 . . .	50 50 50 50 100 100 100 100 rest.
Over 850 . . .	50 50 50 50 100 100 100 100 200 rest.

APPENDIX IV.

SAMPLE PLOT FILE.

Ex. 35.—The following example is based on the 1920 and 1925 measurements of S. P. 1, Upper Bashahr (Punjab), but for the sake of simplicity desirable in an example, it has been assumed that the plot was laid out in the year 1920, and some details have been altered from the original to conform with the procedure laid down in this Code.

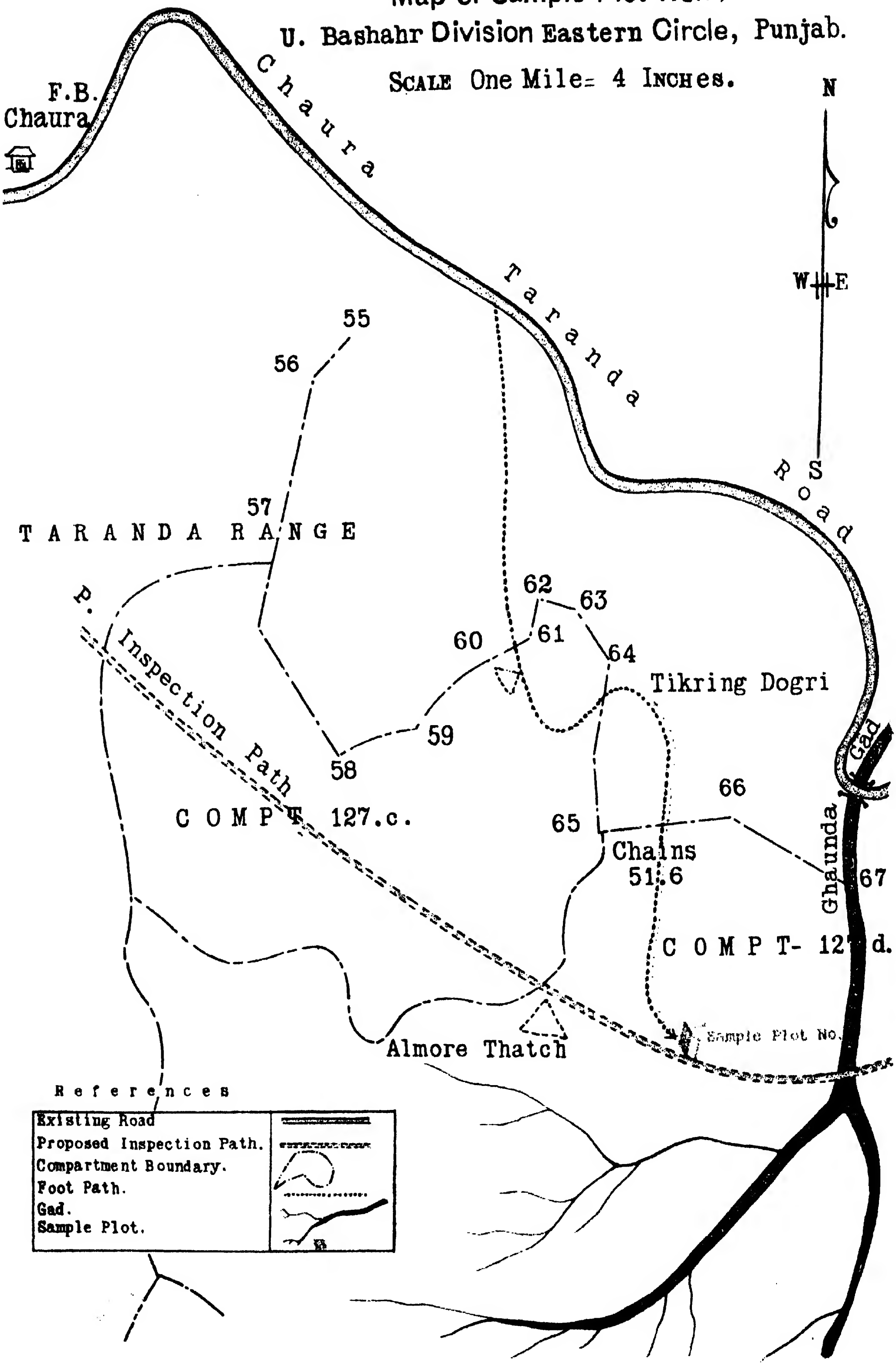
[*The map and the chart occupy pages 147-150.*]

F.R.I. 21.

Sample Plot Form No.1.

Map of Sample Plot No.1,
U. Bashahr Division Eastern Circle, Punjab.

SCALE One Mile = 4 INCHES.



PLOT CHART.

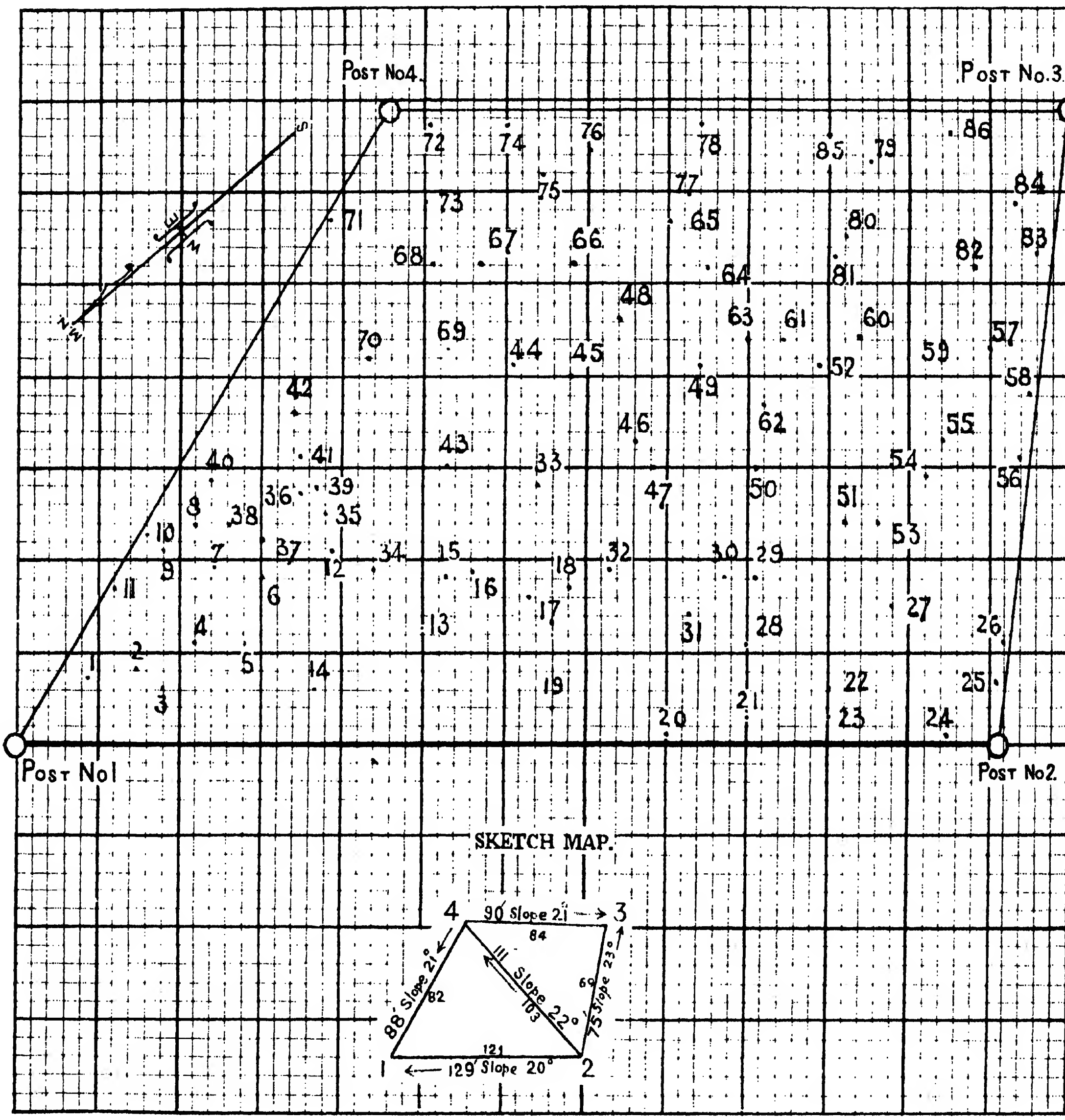
Scale 1" = 20 ft

Experimental Plot

Sample Plot No. 1, Upper Bashahr Division.

Form 5.

(Plane Table Survey.)



F. R. I. 22.

Sample Plot Form No. 2.

Description of Sample Plot No. 1, Upper Bashahr Division.

1. *Species.*—Cedrus Deodara.

2. *Object of experiment.*—Development of thinned deodar crop in volume, height, diameter, etc.

3. *Area in acres.*—0·162 (horizontal).

4. *Situation.*—In Compt. 127*d*, Taranda Range, on the forest inspection path from Chaura to Taranda, 4 miles from Chaura and 5 miles from Taranda ; 51·6 chains from Tikring Dogri.

5. *Height above mean sea level.*—7,000′.

6. *Climate*—

(*a*) *Mean annual rainfall.*—80″.

(*b*) *General.*—Typical West Himalayan wet zone climate.

7. *Rock, soil and humus.*—Mica Schist ; Soil sandy ; humus deep.

8. *Aspect and slope.*—S. S. E. Average slope 21°.

9. *Type of forest.*—Pure pole crop of deodar (natural regeneration).

10. *Age of crop at first measurement.*—[35] 36 years based on 1925 age curve.

11. *Date of formation.*—22 August, 1920.

12. *Interval of measurement.*—10 years with interim measurements after 5 years.

13. *Interval of thinnings.*—10 years after crop is brought into normal condition, 5 years till then.

14. *Method of demarcation.*—Standard, with corner posts and connecting ditches.

15. *Method of numbering and marking trees.*—Standard.

F. R. I. 23.

Sample Plot Form No. 2.

16. *Condition of plot when formed*—

(*a*) *Overwood.*—Crowded in parts, whole plot being fully stocked except for one gap due to delayed removal of a dead tree near trees Nos. 20 and 25. Density 1·2.

(*b*) *Underwood.*—Nil.

(*c*) *Weed growth.*—Very little owing to density of the crop. An occasional woody shrub of *Indigofera*, *Desmodium*, etc. A little grass in the more open patch.

(*d*) *Regeneration of principal species.*—None.

17. *Details of work carried out at first formation.*—Thinned to a "C" grade thinning (not recorded the area remaining overstocked.

18. *Details of treatment to be applied.*—A "C" grade thinning when required.

19. *Remarks.*—To be compared with the adjoining S. P. 2 maintained with "B" grade thinning.

Signature.

A. B. C.

F. R. I. 23.
Sample Plot Form No. 2.

Subsequent History of Sample Plot No. 1, Upper Bushahr Division.

Date.	Particulars.
May 20th, 1925.	Measured and thinned "C" grade, still overstocked, 10 stems with average diameter 7·7" removed.
	(Sd.) *X. Y. Z.*

F. R. I. 23.
Sample Plot Form No. 2.

Subsequent History of Sample Plot No. *Division.*

Date.	Particulars.

F. R. I. 24. Sample Plot Form No. 3.

Record of diameter measurements.

Sample Plot No. 1, Upper Bashahr Division.

Tree No.	Species.	Height at which measurement is taken.	Diameters at right angles in inches and decimals, and condition recorded in the year (D1-Predominant, D2-Co-dominant, d-dominated, s-suppressed). 1920. August.	1925, May.	19 .	19 .	19 .	19 .	Trees removed and their condition. Year.	Diameters at right angles.
1	Cedrus Deodara . .	4'-6"	3·7/3·9 da	Thinned					1925	4·2/4·2 da
2	Ditto . .	"	5·4/5·4 D1b	6·2/5·7 D1b						
3	Ditto . .	"	5·2/5·2 D2b	5·6/5·8 D2b						
4	Ditto . .	"	5·8/5·7 D2b	6·2/6·4 D2b						
5	Ditto . .	"	7·3/7·1 D2b	8·2/7·7 D2b						
6	Ditto . .	"	7·1/7·3 D2a	7·5/7·9 D2a						
7	Ditto . .	"	8·1/8·0 D1a	8·7/8·4 D1a						
8	Ditto . .	4'-9"	6·5/6·7 D2b	7·0/7·2 D2b						
9	Ditto . .	4'-6"	8·7/8·3 D2a	9·4/9·0 D2a						
10	Ditto . .	"	8·5/8·5 D1a	9·1/9·0 D1a						
11	Ditto . .	"	7·3/7·3 D1a	8·1/7·9 D1a						
12	Ditto . .	"	8·3/8·2 D1a	9·0/8·8 D1a						
13	Ditto . .	"	7·9/8·2 D2b	8·6/8·9 D2b						
14	Ditto . .	"	7·6/7·9 da	Thinned					1925	7·9/7·9 da
15	Ditto . .	"	7·0/6·9 D2b*	7·8/8·2 D2b						
16	Ditto . .	"	10·3/10·5 D1a	11·1/11·3 D1a						
17	Ditto . .	"	4·1/4·3 s	Thinned					1925	4·2/4·4 s
18	Ditto . .	"	10·1/9·8 D1a	10·4/10·1 D1a						
19	Ditto . .	"	7·6/8·1 D1a	8·0/8·8 D1a						
20	Ditto . .	"	11·4/11·2 D1a	12·1/12·0 D1a						
21	Ditto . .	"	7·7/7·9 D2b*	8·0/8·3 D2b						
22	Ditto . .	"	10·1/10·3 D1a	11·0/11·3 D1a						
23	Ditto . .	"	6·8/7·1 D1a	7·3/7·1 D1a						
24	Ditto . .	"	10·5/10·2 D1a	11·3/10·9 D1a						
25	Ditto . .	"	11·7/11·7 D1a	13·2/12·9 D1a						
26	Ditto . .	"	11·3/11·8 D1a	11·9/12·7 D1a						
27	Ditto . .	"	6·1/6·2 D2b	6·4/6·4 D2b						
28	Ditto . .	"	9·2/9·1 D2a	9·5/9·5 D2a						
29	Ditto . .	"	10·1/9·9 D1a	10·7/10·5 D1a						

* Leader lost from snow-break.

F. R. I. 24. Sample Plot Form No. 8.

Record of diameter measurements.

Sample Plot No. 1, Upper Bashahr Division.

Tree No.	Species.	Height at which measurement is taken.	Diameters at right angles in inches and decimals, and condition recorded in the year [D1-Predominant, D2-Codominant, d-dominated, s-suppressed].						Trees removed and their condition.	
			1920, August.	1925, May.	19 .	19 .	19 .	.	Year.	Diameters at right angles.
30	Cedrus Deodara . .	4′-6″	$\frac{9{\cdot}0}{8{\cdot}8}$ D1*a*	$\frac{9{\cdot}9}{9{\cdot}9}$ D1*a*						
31	Ditto . .	..	$\frac{9{\cdot}3}{9{\cdot}4}$ D1*b*	$\frac{9{\cdot}8}{10{\cdot}0}$ D1*b*						
32	Ditto . .	..	$\frac{8{\cdot}2}{8{\cdot}3}$ D1*b*	$\frac{8{\cdot}8}{9{\cdot}2}$ D1*b*						
33	Ditto . .	..	$\frac{11{\cdot}2}{11{\cdot}3}$ D1*a*	$\frac{12{\cdot}3}{12{\cdot}1}$ D1*a*						
34	Ditto . .	..	$\frac{11{\cdot}1}{11{\cdot}1}$ D1*a*	$\frac{11{\cdot}9}{12{\cdot}0}$ D1*a*						
35	Ditto . .	..	$\frac{11{\cdot}1}{10{\cdot}8}$ D1*b*	$\frac{11{\cdot}6}{11{\cdot}4}$ D1*b*						
36	Ditto . .	..	$\frac{8{\cdot}5}{8{\cdot}6}$ D1*b*	Thinned					1925	$\frac{9{\cdot}1}{9{\cdot}3}$ D1*b*
37	Ditto . .	..	$\frac{6{\cdot}7}{6{\cdot}8}$ D2*b*	$\frac{7{\cdot}6}{7{\cdot}9}$ D2*b*						
38	Ditto . .	..	$\frac{6{\cdot}5}{6{\cdot}6}$ *db*	$\frac{6{\cdot}9}{6{\cdot}9}$ *db*						
39	Ditto . .	..	$\frac{6{\cdot}5}{6{\cdot}5}$ *da*	$\frac{7{\cdot}1}{7{\cdot}0}$ *da*						
40	Ditto . .	..	$\frac{7{\cdot}6}{7{\cdot}8}$ D2*a*	$\frac{8{\cdot}2}{8{\cdot}6}$ D2*a*						
41	Ditto . .	..	$\frac{8{\cdot}3}{7{\cdot}6}$ D2*b*	$\frac{8{\cdot}7}{8{\cdot}3}$ D2*b*						
42	Ditto . .	..	$\frac{10{\cdot}3}{9{\cdot}7}$ D1*a*	$\frac{11{\cdot}1}{10{\cdot}5}$ D1*a*						
43	Ditto . .	..	$\frac{4{\cdot}9}{5{\cdot}0}$ *da*	Thinned					1925	$\frac{5{\cdot}0}{5{\cdot}2}$ *da*
44	Ditto . .	..	$\frac{11{\cdot}1}{11{\cdot}1}$ D1*a*	$\frac{11{\cdot}6}{11{\cdot}8}$ D1*a*						
45	Ditto . .	..	$\frac{12{\cdot}1}{12{\cdot}0}$ D1*a*	$\frac{12{\cdot}9}{12{\cdot}9}$ D1*a*						
46	Ditto . .	..	$\frac{8{\cdot}5}{9{\cdot}3}$ D1*a*	$\frac{9{\cdot}3}{10{\cdot}0}$ D1*a*						
47	Ditto . .	..	$\frac{3{\cdot}3}{6{\cdot}9}$ D2*b*	$\frac{6{\cdot}6}{7{\cdot}2}$ D2*b*						
48	Ditto . .	..	$\frac{11{\cdot}1}{11{\cdot}0}$ D1*a*	$\frac{11{\cdot}8}{11{\cdot}6}$ D1*a*						
49	Ditto . .	..	$\frac{5{\cdot}8}{6{\cdot}3}$ *da*	$\frac{6{\cdot}4}{6{\cdot}6}$ *da*						
50	Ditto . .	..	$\frac{7{\cdot}9}{8{\cdot}1}$ D1*a*	$\frac{8{\cdot}3}{8{\cdot}5}$ D1*a*						
51	Ditto . .	..	$\frac{9{\cdot}7}{9{\cdot}7}$ D1*a*	$\frac{10{\cdot}6}{10{\cdot}5}$ D1*a*						
52	Ditto . .	..	$\frac{10{\cdot}2}{10{\cdot}5}$ D1*a*	$\frac{11{\cdot}3}{11{\cdot}1}$ D1*a*						
53	Ditto . .	..	$\frac{10{\cdot}7}{10{\cdot}5}$ D1*a*	$\frac{11{\cdot}5}{11{\cdot}4}$ D1*a*						
54	Ditto . .	..	$\frac{6{\cdot}1}{6{\cdot}2}$ *da*	Thinned					1925	$\frac{6{\cdot}4}{6{\cdot}5}$ *da*
55	Ditto . .	..	$\frac{10{\cdot}6}{11{\cdot}4}$ D1*a*	$\frac{12{\cdot}5}{12{\cdot}3}$ D1*a*						
56	Ditto . .	..	$\frac{10{\cdot}1}{10{\cdot}0}$ D1*a*	$\frac{11{\cdot}0}{11{\cdot}1}$ D1*a*						
57	Ditto . .	..	$\frac{11{\cdot}2}{11{\cdot}4}$ D1*a*	$\frac{11{\cdot}6}{12{\cdot}0}$ D1*a*						
58	Ditto . .	..	$\frac{11{\cdot}5}{11{\cdot}3}$ D1*a*	$\frac{12{\cdot}3}{12{\cdot}1}$ D1*a*						

F. R. 1. 24. Sample Plot Form No. 3.

Record of diameter measurements.

Sample Plot No. 1, Upper Bashahr Division.

Tree No.	Species.	Height at which measurement is taken.	Diameters at right angles in inches and decimals, and condition recorded in the year [D1-Predominant, D2-Co-dominant, d-dominated, s-suppressed].						Trees removed and their condition.	
			1920. August.	1925, May.	19 .	19 .	19 .	19 .	Year.	Diameters at right angles.
59	Cedrus Deodara . .	4'-6"	7·5/7·7 D1*a*	8·2/8·6 D1*a*						
60	Ditto . .	..	7·9/7·9 D2*a*	8·0/8·3 D2*a*						
61	Ditto . .	..	5·8/6·4 *db*	6·0/6·6 *db*						
62	Ditto . .	..	11·4/10·8 D1*a*	Thinned					1925	12·0/11·3 D1*a*
63	Ditto . .	..	5·8/6·2 D2*b*	6·6/6·4 D2*b*						
64	Ditto . .	..	7·4/7·0 *da*	8·0/7·4 *da*						
65	Ditto . .	..	7·4/7·5 *db*	7·9/7·9 *db*						
66	Ditto . .	..	9·2/9·5 D1*a*	10·4/10·4 D1*a*						
67	Ditto . .	..	7·2/7·3 D2*b*	7·7/7·7 D2*b*						
68	Ditto . .	..	9·8/9·1 D1*a*	10·8/10·9 D1*a*						
69	Ditto . .	,,	8·8/8·9 D1*b*	9·8/9·3 D1*b*						
70	Ditto . .	..	9·0/8·7 D1*a*	10·2/9·4 D1*a*						
71	Ditto . .	..	10·8/10·4 D1*a*	Thinned					1925	11·8/11·2 D1*a*
72	Ditto . .	..	11·8/10·5 D1*a*	12·8/11·5 D1*a*						
73	Ditto . .	,,	7·3/7·4 *db*	Thinned					1925	7·5/7·2 *db*
74	Ditto . .	..	11·7/11·0 D1*a*	13·4/12·7 D1*a*						
75	Ditto . .	..	13·8/13·3 D1*a*	15·1/14·0 D1*a*						
76	Ditto . .	..	13·5/12·8 D1*a*	14·2/13·3 D1*a*						
77	Ditto . .	..	13·2/12·4 D1*a*	14·4/13·2 D1*a*						
78	Ditto . .	..	9·5/8·9 D1*a*	10·4/9·8 D1*a*						
79	Ditto . .	,,	10·5/10·2 D1*a*	11·4/10·9 D1*a*						
80	Ditto . .	..	12·7/12·8 D1*a*	13·4/13·2 D1*a*						
81	Ditto . .	,,	9·8/10·2 D1*a*	11·0/11·0 D1*a*						
82	Ditto . .	..	9·7/10·5 D1*a*	10·6/11·2 D1*a*						
83	Ditto . .	..	8·8/9·0 D2*b*	8·9/9·2 D2*b*						
84	Ditto . .	,,	4·3/4·4 s	Thinned					1925	4·3/4·7 s
85	Ditto . .	..	10·6/10·7 D1*a*	11·5/11·6 D1*a*						
86	Ditto . .	,,	10·9/10·7 D1*a*	11·6/11·4 D1*a*						
		Initials .	A. B. C.	X. Y. Z.						

F. R. I. 25.

Sample Plot Form No. 4.

Measurements of Sample Trees.

Sample Plot No. 1, Upper Bashahr Division.

Sample Tree No.	Species.	Age.	Total Height.	Length of shoot of last 5 years.	Diameters at 4½ ft. At right angles.		Diameters at 4½ ft. Average.	Basal area at 4½'.	Volume measurements. Timber. Stem.	Volume measurements. Timber. Branch.	Volume measurements. Smallwood. Stem.	Volume measurements. Smallwood. Branch.	Volume of cylinder.	Form factors. Timber. Stem.	Form factors. Timber. Branch.	Form factors. Smallwood. Stem.	Form factors. Smallwood. Branch.	Bark thickness at 4½ ft.	Bark %	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
									August 1920.											
1		37	75	—	13·2	13·1	13·2	0·9501	22·2781	0	3·2245	0	71·2800	·313	0	·045	0	0·50	14	
2		37	57	—	10·1	10·2	10·2	0·5675	9·1116	0	2·6054	0	32·3475	·283	0	·081	0	0·35	15	
3	Cedrus Deodara.	37	61	—	9·0	8·6	8·8	0·4224	4·2042	0	5·9923	0	25·7664	·163	0	·233	0	0·30	14	
4		31	57	—	6·5	6·3	6·4	0·2234	0	0	5·1978	0	12·7338	0	0	·408	0	0·25	17	
5		31	35	—	5·4	5·3	5·4	0·1590	0	0	1·8953	0	5·5650	0	0	·341	0	0·25	20	
A		34	40	—	4·3	4·3	4·3	0·1009	0	0	1·4573	0	4·0360	0	0	·361	0	0·15	15	
									May 1925.											
A		50	75	7·9′	12·3	13·6	13·0	0·9218	22·9514	0	4·3807	0	69·1350	·332	0	·063	0	0·50	14	
1		37	63	5·9′	12·0	11·3	11·7	0·7467	12·0844	0	5·3029	0	47·0421	·257	0	·113	0	0·70	13	
2		37	70	7·8′	11·8	11·2	11·5	0·7214	14·5182	0	4·8072	0	50·4980	·288	0	·095	0	0·60	10	
3	Cedrus Deodara.	37	66	5·0′	9·1	9·3	9·2	0·4617	6·6293	0	7·1562	0	30·4722	·218	0	·235	0	0·35	20	
4		35	60	8·7′	7·5	7·2	7·4	0·2987	0	0	7·3670	0	17·9220	0	0	·411	0	0·35	17	
5		39	50	5·3′	6·4	6·5	6·5	0·2304	0	0	5·2530	0	11·5200	0	0	·456	0	0·25	14	
6		38	51	3·7′	5·0	5·2	5·1	0·14[illegible]	0	0	3·2163	0	7·2318	0	0	·445	0	0·25	17	

F. R. I. 26. Sample Plot Form No. 5.

Volume calculation for Sample Plot No. 1, Upper Bashahr Division, dated 21st October, 1920,

Initials M. N. O.

(Two diameters and double calculation throughout.)

By diameter classes.			By groups.		Calculated mean tree.						Volume.		
								Form factor.				Small wood.	
									Small wood.				
Diameter.	Number of diameters.	Basal area.	Number of diameters.	Basal area.	Basal area.	Diameter.	Height.	Stem Timber.	Stem.	Total.	Stem Timber.	Stem.	Total.
Inch class.		Sq. ft. and dec.		Sq. ft. and dec.	Sq. ft. and dec.	In. and dec.	Feet.				Cub. ft. and dec.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
						MAIN CROP, 1920.							
14	2	2·1380											
13	5	4·6090											
12	1	0·7854	8	7·5324	0·9416	13·1	75	·312	·046	·046	176·26	25·99	25·99
12	8	6·2832	8	6·2832	0·7854	12·0	72	·305	·057	·057	137·98	25·79	25·79
11	8	5·2800	8	5·2800	0·6600	11·0	69	·292	·078	·078	106·38	28·42	28·42
11	8	5·2800	8	5·2800	0·6000	11·0	69	·292	·078	·078	106·38	28·42	28·42
11	16	10·5600	16	10·5000	0·6600	11·0	69	·292	·078	·078	212·76	56·83	56·83
11	2	1·3200											
10	14	7·6356	16	8·9556	0·5597	10·1	66	·267	·107	·107	157·82	63·24	63·24
10	9	4·9086											
9	7	3·0926	16	8·0012	0·5001	9·6	64	·243	·137	·137	124·43	70·15	70·15
9	15	6·6270											
8	1	0·3491	16	6·9761	0·4360	8·9	61	·193	·193	·193	82·13	82·13	82·13
8	25	8·7275	25	8·7275	0·3491	8·0	57	·090	·289	·289	44·77	143·77	143·77
7	26	6·9498											
6	13	2·5519											
5	6	0·8184											
4	6	0·5238	51	10·8439	0·2126	6·2	47	0	·407	·407	0	207·43	207·43
4"-14"			172	78·4399	0·4560	9·1	64	·229	·146	·146	1148·91	732·17	732·17

F. R. I. 26. Sample Plot Form No. 5.

Volume calculation for Sample Plot No. 1, Upper Bashahr Division, dated 25th October, 1926.

Initials R. S. T.

(Two diameters and double calculation throughout.)

By diameter classes.			By groups.		Calculated mean tree.						Volume.		
								Form factor.				Small wood.	
									Small wood.				
Diameter.	Number of diameters.	Basal area.	Number of diameters.	Basal area.	Basal area.	Diameter.	Height.	Stem Timber.	Stem.	Total.	Stem Timber.	Stem.	Total.
Inch class.		Sq. ft. and dec.		Sq. ft. and dec.	Sq. ft. and dec.	In. and dec.	Feet.				Cub. ft. and dec.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
						Main Crop, 1925.							
15	1	1·2272											
14	3	3·2070											
13	4	3·6872	8	8·1214	1·0152	13·6	79	·328	·050	·050	210·44	32·08	32·08
13	8	7·3744	8	7·3744	0·9218	13·0	77	·320	·054	·054	181·71	30·66	30·66
13	1	0·9218											
12	7	5·4978	8	6·4196	0·8025	12·1	73	·306	·065	·065	143·40	30·46	30·46
12	8	6·2832	8	6·2832	0·7854	12·0	73	·304	·067	·067	139·44	30·73	30·73
12	7	5·4978											
11	9	5·9400	16	11·4378	0·7149	11·4	71	·293	·079	·079	237·94	64·15	64·15
11	16	10·5600	16	10·5600	0·6600	11·0	69	·283	·089	·089	206·21	64·85	64·85
11	2	1·3200											
10	14	7·6356	16	8·9556	0·5597	10·1	66	·254	·130	·130	150·13	76·84	76·84
10	1	0·5454											
9	15	6·6270	16	7·1724	0·4483	9·1	62	·199	·222	·222	88·49	98·72	98·72
9	6	2·6508											
8	25	8·7275	31	11·3785	0·3670	8·2	59	·119	·337	·337	79·89	226·23	226·23
7	14	3·7422											
6	11	2·1593	25	5·9015	0·2361	6·6	52	0	·450	·450	0	138·10	138·10
6"-15"			152	83·6042	0·5500	10·0	68	·253	·139	·139	1437·65	792·82	792·82

F. R. I. 26. Sample Plot Form No. 5.

Volume calculation for Sample Plot No. 1, Upper Bashahr Division, dated 25th October, 1926,

Initials R. S. T.

(Two diameters and double calculation throughout.)

By diameter classes.			By groups.		Calculated mean tree.						Volume.		
								Form factor.				Small wood.	
									Small wood.				
Diameter.	Number of diameters.	Basal area.	Number of diameters.	Basal area.	Basal area.	Diameter.	Height.	Stem Timber.	Stem.	Total.	Stem Timber.	Stem.	Total.
Inch class.		Sq. ft. and dec.		Sq. ft. and dec.	Sq. ft. and dec.	In. and dec.	Feet.				Cub. ft. and dec.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					SUBSIDIARY CROP, 1925.								
12	2	1·5708											
11	2	1·3200											
9	2	0·8836											
8	3	1·0473	9	4·8217	0·5357	9·9	65	·245	·144	·144	76·79	45·13	45·13
7	2	0·5346											
6	1	0·1963											
5	3	0·4092											
4	5	0·4365	11	1·5766	0·1433	5·1	45	0	·375	·375	0	26·61	26·61
4" to 12"			20	6·3983	0·3199	7·7	60				76·79	71·74	71·74

F. R. 1. 26. Sample Plot Form No. 5.

Volume calculation for Sample Plot No. 1, Upper Bashahr Division, dated 25th October, 1926,
Initials R. S. T.

1920 calculations back checked with 1925 (Two diameters and double calculation throughout.)

By diameter classes.			By groups.		Calculated mean tree.						Volume.		
								Form factor.				Small wood.	
									Small wood.				
Diameter.	Number of diameters.	Basal area.	Number of diameters.	Basal area.	Basal area.	Diameter.	Height.	Stem Timber.	Stem.	Total.	Stem Timber.	Stem.	Total.
Inch class.		Sq. ft. and dec.		Sq. ft. and dec.	Sq. ft. and dec.	In. and dec.	Feet.				Cub. ft. and dec.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
						MAIN CROP, 1920.							
14	2	2·1380											
13	5	4·6090											
12	1	0·7854	8	7·5324	0·9416	13·1	73	·322	·053	·053	177·06	29·14	29·14
12	8	6·2832	8	6·2832	0·7854	12·0	69	·301	·067	·067	131·80	29·05	29·05
11	8	5·2800	8	5·2800	0·6600	11·0	66	·283	·089	·089	98·62	31·01	31·01
11	8	5·2800	8	5·2800	0·6600	11·0	66	·283	·089	·089	98·62	31·01	31·01
11	15	9·9000											
10	1	0·5454	16	10·4454	0·6528	10·9	65	·281	·093	·093	190·79	63·14	63·14
10	16	8·7264	16	8·7264	0·5454	10·0	62	·249	·137	·137	134·72	74·12	74·12
10	5	2·7270											
9	11	4·8598	16	7·5868	0·4742	9·3	50	·212	·198	·198	94·90	88·63	88·63
9	9	3·9762											
8	7	2·4437	16	6·4199	0·4012	8·6	57	·158	·286	·286	57·82	104·66	104·66
8	17	5·9347											
7	14	3·7422	31	9·6769	0·3122	7·6	53	·039	·402	·402	20·00	206·18	206·18
7	10	2·6730											
6	11	2·1593											
5	4	0·5456	25	5·3779	0·2151	6·3	47	0	·448	·448	0	113·24	113·24
5" to 14"			152	72·6089			*[62]				1004·33	770·18	770·18
4" to 11"			20	5·8310							56·96	69·76	69·76
4" to 14"			172	78·4899	0·4560	9·1	61	·222	·176	·176	1061·29	839·94	839·94

* *Cf.* Step 35, p. 134.

F. R. I. 20. Sample Plot Form No. 5.

Volume calculation for Sample Plot No. 1, Upper Bashahr Division, dated 25th October, 1926,
Initials R. S. T.

1920 calculations back checked with 1925. (Two diameters and double calculation throughout.)

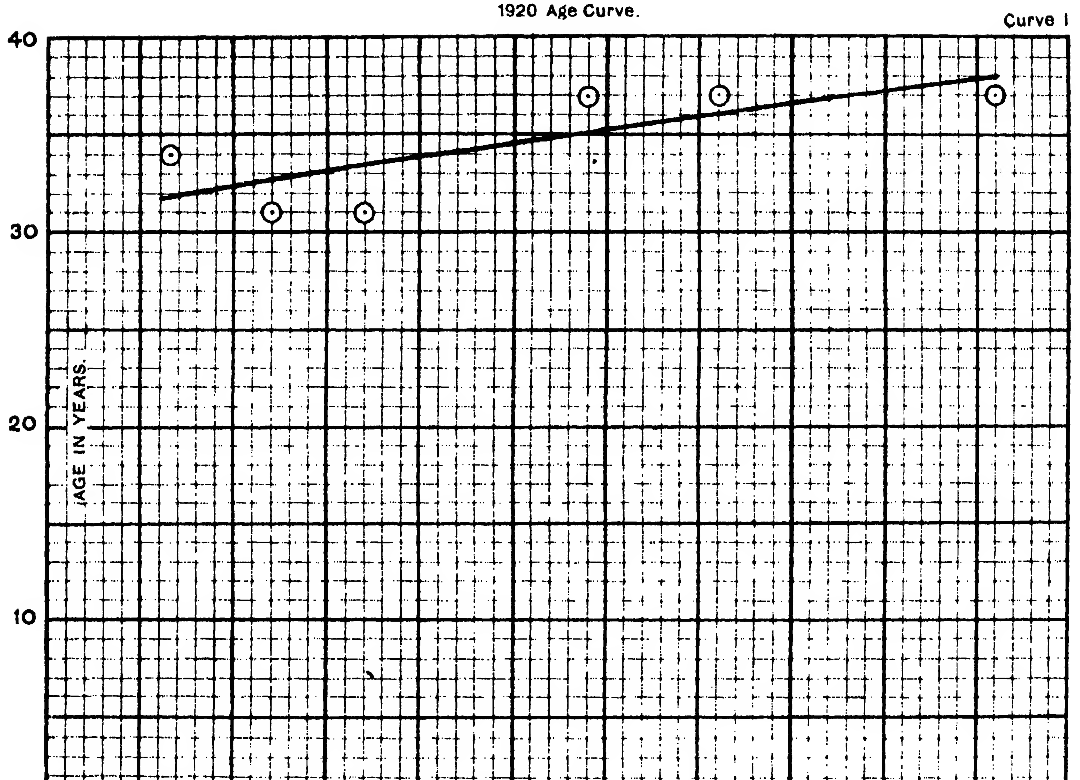
By diameter classes.			By groups.		Calculated mean tree.						Volume.		
								Form factor.				Small wood.	
									Small wood.				
Diameter.	Number of diameters.	Basal area.	Number of diameters.	Basal area.	Basal area.	Diameter.	Height.	Stem Timber.	Stem.	Total.	Stem Timber.	Stem.	Total.
Inch class.		Sq. ft. and dec.		Sq. ft. and dec.	Sq. ft. and dec.	In. and dec.	Feet.				Cub. ft. and dec.		
1	2	3	4	5	6	7	8	9	10	11	12	13	14
					MAIN CROP, 1920—*contd.*								
11	3	1·9800											
10	1	0·5454											
9	2	0·8836											
8	2	0·6982											
7	1	0·2673	9	4·3745	0·4861	9·4	60	·217	·187	·187	56·96	49·08	49·08
7	1	0·2673											
6	2	0·3926											
5	2	0·2728											
4	6	0·5238	11	1·4565	0·1324	4·9	40	0	·355	·355	0	20·68	20·68
4" to 11"			20	5·8310							56·96	69·76	69·76

(*The curves occupy pages 169—181.*)

SAMPLE PLOT NO. 1, UPPER BASHAHR DIVISION.

Cedrus Deodara.

1920 Age Curve.

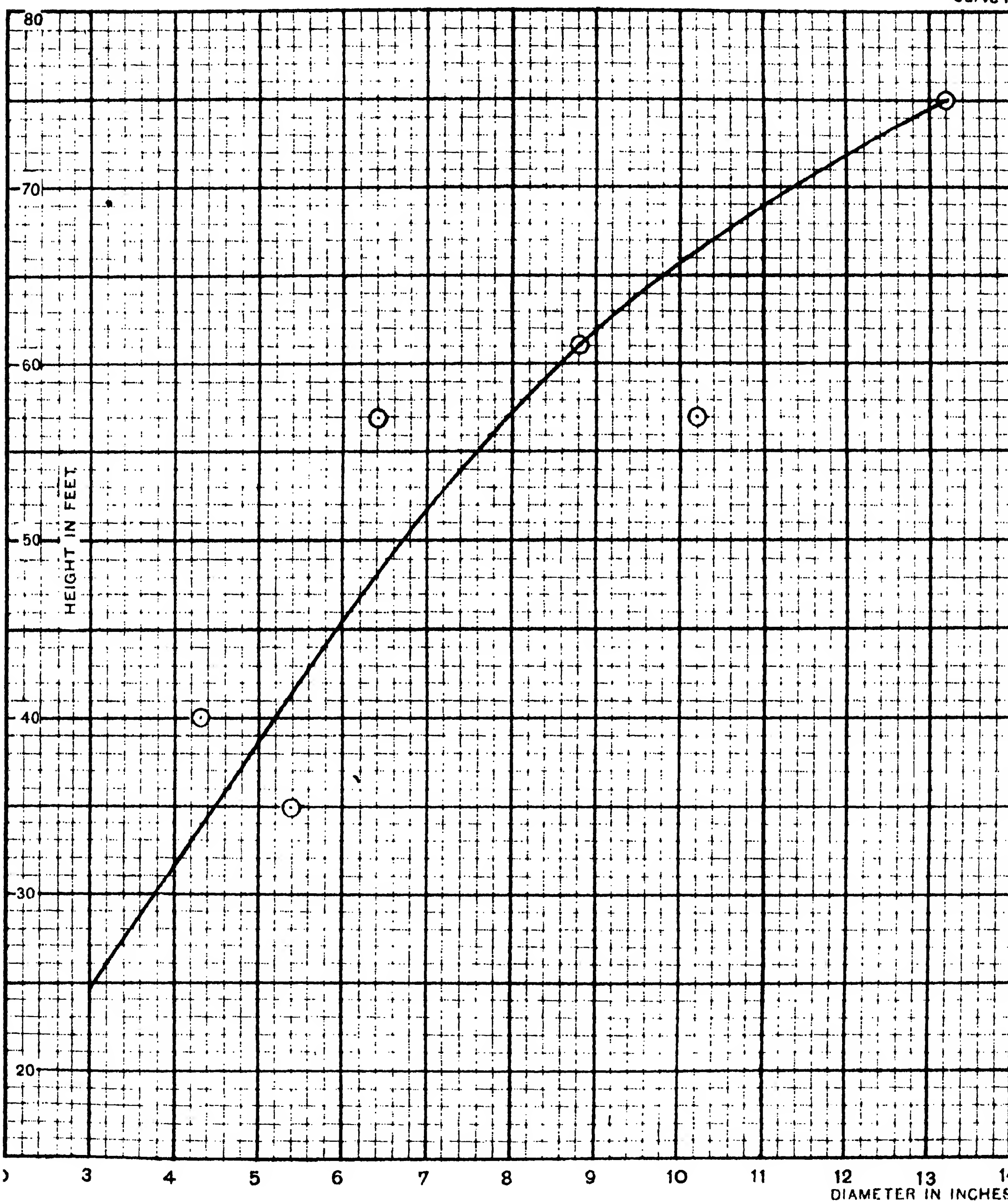


SAMPLE PLOT NO. 1, UPPER BASHAHR DIVISION.

Cedrus Deodara.

1920 Height Curve.

Curve II



SAMPLE PLOT NO. 1, UPPER BASHAHR DIVISION.

Cedrus Deodara.

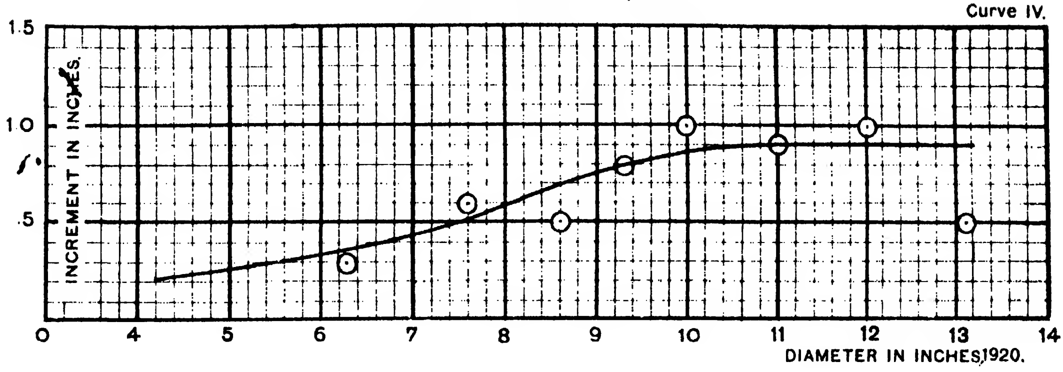
1920 Form Factor Curves.

SAMPLE PLOT NO. 1, UPPER BASHAHR DIVISION.

Cedrus Deodara.

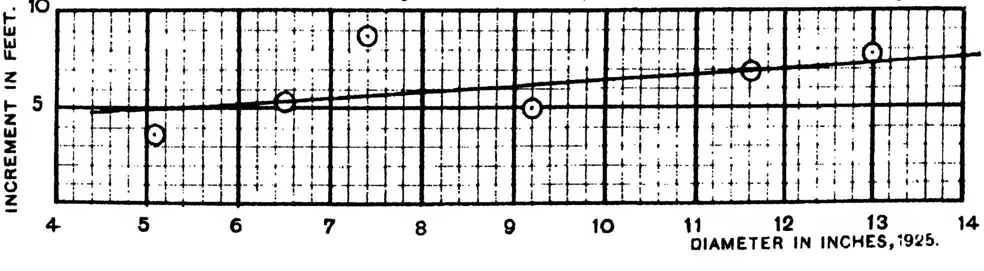
Diameter Increment Curve, 1920-25.

Curve IV.



Height Increment Curve, 1920-25.

Curve V



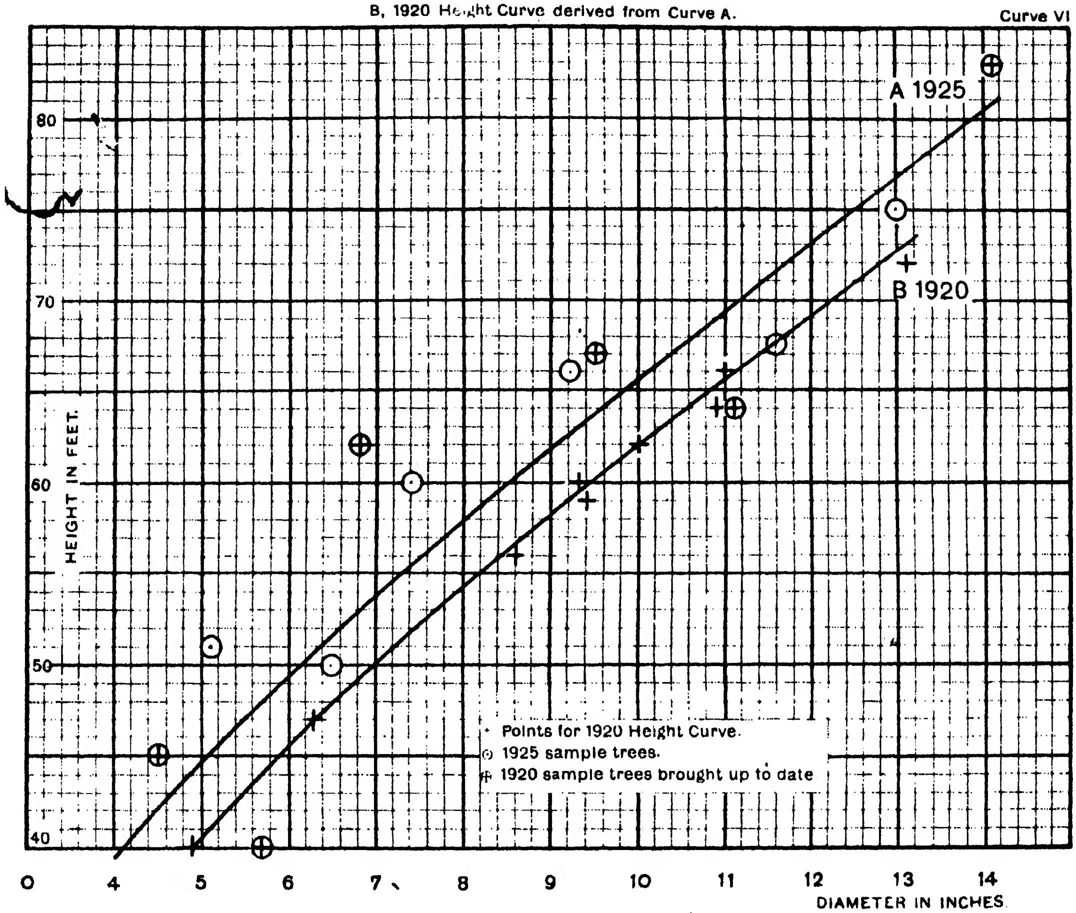
SAMPLE PLOT NO. 1, UPPER BASHAHR DIVISION.

Cedrus Deodara.

A. 1925 Height Curve.

B. 1920 Height Curve derived from Curve A.

Curve VI



Calculation of 1925 diameter and height of 1920 sample trees.

Diam. in 1920	Increment	Diam. in 1925	Height in 1920	Increment	Height for 1925
13·2	·9	14·1	75	8	83
10·2	·9	11·1	57	7	64
8·8	·7	9·5	61	6	67
6·4	·4	6·8	57	5	62
5·4	·3	5·7	35	5	40
4·3	·2	4·5	40	5	45

Calculation of 1920 heights of 1925 groups (main crop).

Diam. of 1925 groups	13·6	13·0	12·1	12·0	11·4	11·0	10·1	9·1	8·2	6·6
Heights of 1925 groups	79	77	73	73	71	69	66	62	59	52
Increment 1920–25	7	7	7	7	7	7	6	6	6	5
Height of 1925 groups in 1920	72	70	66	65	64	62	60	56	53	47
Diam. of 1920 groups	13·1	12·0	11·0	11·0	10·9	10·0	9·3	8·6	7·5	6·3

SAMPLE PLOT NO. 1. UPPER BASHAHR DIVISION.

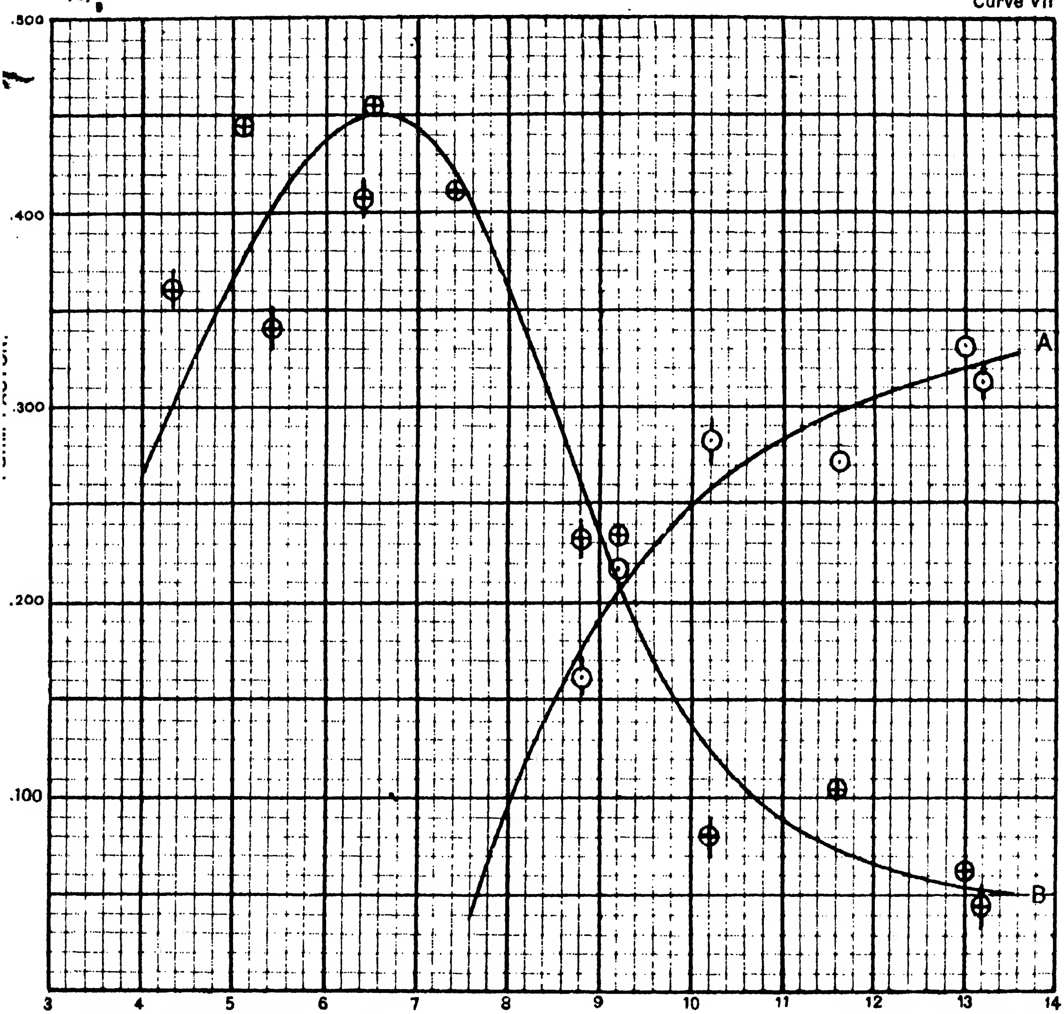
Cedrus Deodara.

Combined (1920 & 1925) Form Factor Curves,

A. Stem timber.

B. Stem (and total) smallwood.

Curve VII



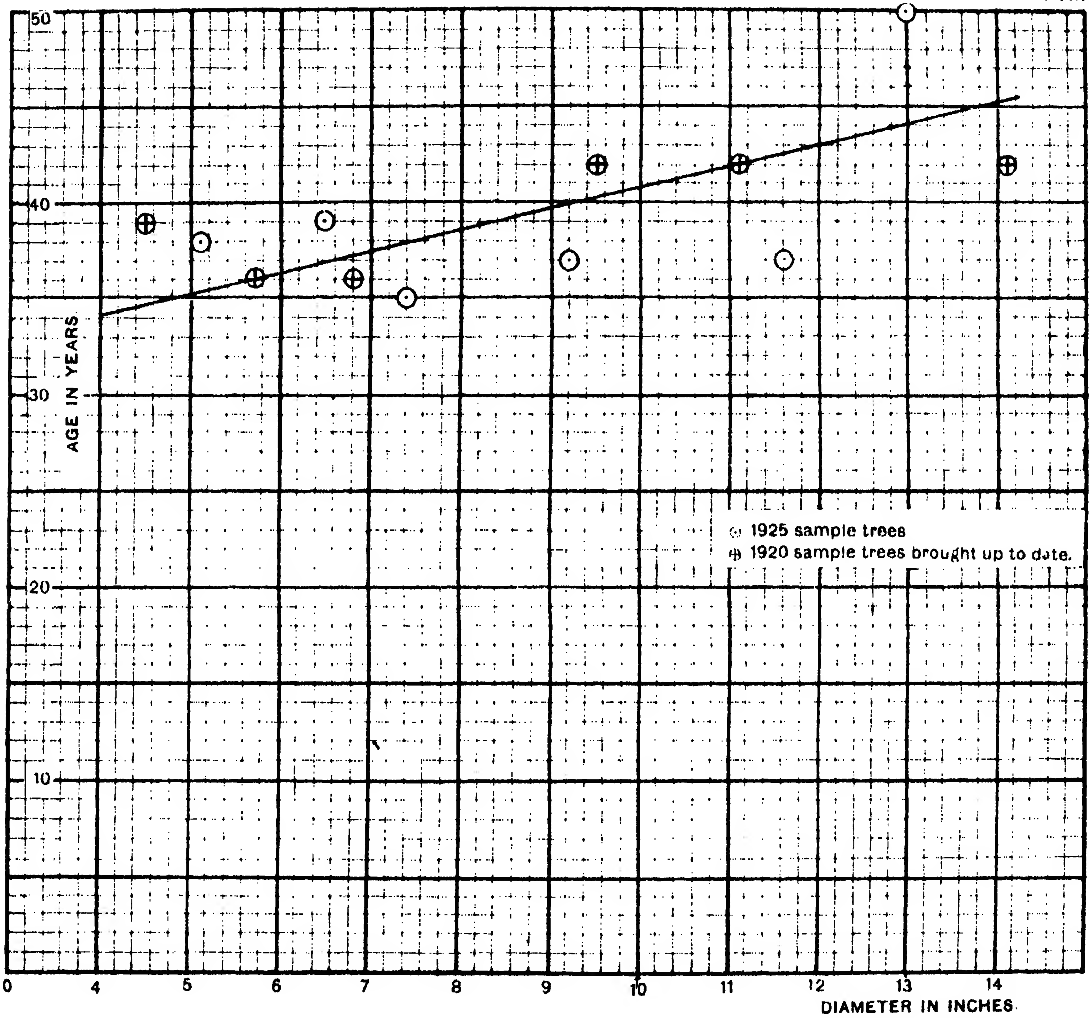
⊙ Stem timber Form factor .. 1925
Do. .. 1920
⊕ Stem smallwood Form factor 1925
Do. ... 1920

SAMPLE PLOT NO. 1, UPPER BASHAHR DIVISION

Cedrus Deodara.

1925 Age Curve.

Curve VIII



F. R. I. 27.

Record of Periodical Volume

Sample Plot No. 1,

Year of measurement.	Age of crop.	Species.	Main Crop: Number of trees per acre after thinning.	Height: Average of tallest trees.	Height: Average of crop.	Form factors: Stem Timber.	Form factors: Small wood: Stem.	Form factors: Small wood: Total.	Diameters: Minimum.	Diameters: Maximum.	Diameters: Average.	Basal area per acre after thinning.	Volume per acre: Stem Timber.	Volume per acre: Small wood: Stem.	Volume per acre: Small wood: Branch.	Volume per acre: Total.
	Years.			Feet.					Inches and dec.			Sq. ft. and dec.	Solid cub. ft.			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1920 (August)	[35]	Cedrus Deodara.	531	[75]	[64]	[·229]	[·146]	[·146]	4	14	9·1	242·1	[3,546]	[2,200]	[0]	[5,806]
	36			73	61	·222	·176	·176					3,276	2,592	0	5,868
1925 (May) .	41		469	79	68	·253	·139	·139	6	15	10·0	258·0	4,437	2,447	0	6,884

Sample Plot Form No. 6.

MEASUREMENTS PER ACRE.

Upper Bashahr Division.

Intermediate yield from thinnings.										Total Crop.		Increment of final crop.			
		Diameters.				Volume per acre.						Periodic.		Periodic mean.	
							Small wood.								
Number of trees per acre.	Average height.	Minimum.	Maximum.	Average.	Basal area per acre.	Stem Timber.	Stem.	Branch.	Total.	Basal area.	Stem Timber.	Basal area.	Stem Timber.	Basal area.	Stem Timber.
	Feet.	Inches and dec.			Sq. ft. and dec.	Solid cub. ft.				Sq. ft. and dec.	Solid cub. ft.	Sq. ft.	Solid cub. ft.	Sq. ft.	Solid cub. ft.
18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
Thinning not recorded.										Unk.	Unk.				
62	60	4	12	7·7	19·7	237	221	0	458	277·7	4,671	35·6	1,398	7·1	280

F. R. I. 64. Sample Plot Form No. 8.

RECORD OF DIAMETER MEASUREMENTS.

Sample Plot No. 1, Upper Bashahr Division, dated 17th August 1920, Initials A. B. C.

Tree No.	Species.	Two diameters at right angles. (Inches and dec.)	Condition.	Remarks.	Tree No.	Species.	Two diameters at right angles. (Inches and dec.)	Condition.	Remarks.
1	Deodar .	$\frac{3\cdot7}{3\cdot9}$	*da*		13	Deodar .	$\frac{7\cdot9}{8\cdot2}$	D2*b*	
2	" .	$\frac{5\cdot4}{5\cdot4}$	D1*b*		14	" .	$\frac{7\cdot6}{7\cdot9}$	*da*	
3	" .	$\frac{5\cdot2}{5\cdot2}$	D2*b*		15	" .	$\frac{7\cdot0}{6\cdot9}$	D2*b*	Leader lost from snowbreak.
4	" .	$\frac{5\cdot8}{5\cdot7}$	D2*b*		16	" .	$\frac{10\cdot3}{10\cdot5}$	D1*a*	
5	" .	$\frac{7\cdot3}{7\cdot1}$	D2*b*		17	" .	$\frac{4\cdot1}{4\cdot3}$	S	
6	" .	$\frac{7\cdot1}{7\cdot3}$	D2*a*		18	" .	$\frac{10\cdot1}{9\cdot8}$	D1*a*	
7	" .	$\frac{8\cdot1}{8\cdot0}$	D1*a*		19	" .	$\frac{7\cdot6}{8\cdot1}$	D1*a*	
8	" .	$\frac{6\cdot5}{6\cdot7}$	D2*b*	[At 4′-9″].	20	" .	$\frac{11\cdot4}{11\cdot2}$	D1*a*	
9	" .	$\frac{8\cdot7}{8\cdot3}$	D2*a*		21	" .	$\frac{7\cdot7}{7\cdot9}$	D2*b*	Leader lost.
10	" .	$\frac{8\cdot5}{8\cdot5}$	D1*a*		22	" .	$\frac{10\cdot1}{10\cdot3}$	D1*a*	
11	" .	$\frac{7\cdot3}{7\cdot3}$	D1*a*		23	" .	$\frac{6\cdot8}{7\cdot1}$	D1*a*	
12	" .	$\frac{8\cdot3}{8\cdot2}$	D1*a*		24	" .	$\frac{10\cdot5}{10\cdot2}$	D1*a*	

NOTE.—Only a sample page of this form is given, *vide* p. 119. This Form 8 should not be used at remeasurement, the previous (1920) Form 3 being used to permit check of growth of each tree.

F. R. I. 28. Sample Plot Form No. 7

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 22nd August 1920.
***Initials*, A. B. C.**

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last - - years.	Diameters at 4½ ft. At right angles.		Diameters at 4½ ft. Average.		Corresponding basal area at 4½ ft.	Diameters at half total height. At right angles.		Diameters at half total height. Average.		Remarks.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
1	Cedrus Deodara.	*37*	75	..	13·2 / 13·1	12·2 / 12·1	*13·2*	*12·2*	*0·9504*	8·1 / 8·3	7·5 / 7·6	*8·2*	*7·6*	Volume of cylinder = *71·2800*. Bark per cent. = *14*. Bark thickness at 4' 6" = *0·50"*.

34 rings on stump, 7" above ground level.
Stump allowance = 3 years.

Volume measurements. Timber down to diameter over bark of 8 inches. Length.	Mid-diameters without bark. At right angles.		Mid-diameters without bark. Average.	Sectional area.	Volume.	Volume measurements. Smallwood down to diameter over bark of 2 inches. Length.	Mid-diameters over bark. At right angles.		Mid-diameters over bark. Average.	Sectional area.	Volume.	Form factors. Timber.	Form factors. Small-wood.	Form factors. Timber and Small-wood.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
10	12·1	11·5	*11·8*	*0·7595*	*7·5950*	10	6·3	6·2	*6·3*	*0·2164*	*2·1640*	*·313*	*·045*	
10	11·1	10·8	*11·0*	*0·6600*	*6·6000*	15	3·6	3·6	*3·6*	*0·0707*	*1·0605*			
10	9·2	9·3	*9·2*	*0·4617*	*4·6170*	25					*3·2245*			
11	7·5	7·6	*7·6*	*0·3151*	*3·4661*									
41					*22·2781*									
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 22nd August 1920.
Initials, A. B. C.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last — years.	Diameters at 4½ ft. At right angles. O. B.	At right angles. U. B.	Average. O. B.	Average. U. B.	Corresponding basal area at 4½ ft.	Diameters at half total height. At right angles. Over bark.	At right angles. Under bark.	Average. Over bark.	Average. Under bark.	Remarks.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
2	Cedrus Deodara.	*37*	57	..	10·1 / 10·2	9·5 / 9·4	*10·2*	*9·5*	*0·5675*	6·1 / 6·2	5·6 / 5·7	*6·2*	*5·7*	Volume of cylinder = *32·3475*. Bark per cent. = *15*. Bark thickness at 4′ 6″ = *0·35″*.

34 rings on stump, 6″ above ground level.
Stump allowance = 3 years.

Volume measurements. Timber down to diameter over bark of 8 inches. Length.	Mid-diameters without bark. At right angles.		Average.	Sectional area.	Volume.	Smallwood down to diameter over bark of 2 inches. Length.	Mid-diameters over bark. At right angles.		Average.	Sectional area.	Volume.	Form factors. Timber.	Small-wood.	Timber and Small-wood.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
10	9·3	9·0	*9·2*	*0·4617*	*4·6170*	10	6·1	6·0	*6·1*	*0·2029*	*2·0290*	*·283*	*·081*	
14	7·7	7·7	*7·7*	*0·3234*	*4·5276*	11	3·1	3·1	*3·1*	*0·0524*	*0·5764*			
24					*9·1446*	21					*2·6054*			
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 22nd August 1920
Initials, A. B. C.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last — years.	Diameters at 4½ ft. At right angles		Diameters at 4½ ft. Average.		Corresponding basal area at 4½ ft.	Diameters at half total height. At right angles		Diameters at half total height. Average.		REMARKS.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
3	Cedrus Deodara.	*37*	61	..	9·0 / 8·6	8·1 / 8·2	*8·8*	*8·2*	*0·4221*	5·6 / 5·5	5·1 / 5·2	*5·6*	*5·2*	Volume of cylinder = *25·7664*. Bark per cent. = *14*. Bark thickness at 4' 6" = *0·30"*.

34 rings on stump, 7" above ground level.
Stump allowance = 3 years.

VOLUME MEASUREMENTS. Timber down to diameter over bark of 8 inches. Length.	Mid-diameters without bark. At right angles.		Average.	Sectional area.	Volume.	Smallwood down to diameter over bark of 2 inches. Length.	Mid-diameters over bark. At right angles.		Average.	Sectional area.	Volume.	FORM FACTORS. Timber.	Small-wood.	Timber and Small-wood.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
13	7·6	7·7	*7·7*	*0·3234*	*4·2042*	10	7·1	7·0	*7·1*	*0·2750*	*2·7500*	*·163*	*·233*	
						10	5·9	5·9	*5·9*	*0·1899*	*1·8990*			
						19	3·6	3·6	*3·6*	*0·0707*	*1·3433*			
						39					*5·9923*			
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 22nd August 1920. Initials, A. B. C.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last— years.	Diameters at 4½ ft.				Corresponding basal area at 4½ ft.	Diameters at half total height.				REMARKS.
					At right angles.		Average.			At right angles.		Average.		
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
4	Cedrus Deodara.	*31*	57	..	6·5 / 6·3	6·0 / 5·8	*6·4*	*5·9*	*0·2234*	4·4 / 4·4	4·0 / 4·0	*4·4*	*4·0*	Volume of cylinder = *12·7338*. Bark per cent. = *17*. Bark thickness at 4' 6" = *0·25"*.

29 rings on stump, 5" above ground level.
Stump allowance = 2 years.

VOLUME MEASUREMENTS.												FORM FACTORS.		
Timber down to diameter over bark of 8 inches.						Smallwood down to diameter over bark of 2 inches.								
Length.	Mid-diameters without bark.			Sectional area.	Volume.	Length.	Mid-diameters over bark.			Sectional area.	Volume.	Timber.	Small-wood.	Timber and Small-wood.
	At right angles.		Average.				At right angles.		Average.					
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
	Nil.					10	5·9	5·8	*5·9*	*0·1899*	*1·8990*	*0*	*·408*	
						10	5·2	5·2	*5·2*	*0·1474*	*1·4740*			
						10	4·7	4·6	*4·6*	*0·1154*	*1·1540*			
						12	3·1	3·2	*3·2*	*0·0559*	*0·6708*			
						42					*5·1978*			
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 22nd August 1920.
Initials, A. B. C.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last — — years.	Diameters at 4½ ft.				Corresponding basal area at 4½ ft.	Diameters at half total height.				REMARKS.
					At right angles.		Average.			At right angles.		Average.		
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark	Under bark.	
5	Cedrus Deodara.	*31*	35	..	5·4 / 5·3	4·9 / 4·8	*5·4*	*4·9*	*0·1590*	2·8 / 2·8	2·5 / 2·4	*2·8*	*2·5*	Volume of cylinder = *5·5650.* Bark per cent. = *20* Bark thickness at 4′ 6″ = *0·25″.*

29 rings on stump, 4″ above ground level.
Stump allowance = 2 years.

Volume measurements.												Form factors.		
Timber down to diameter over bark of 8 inches.						Smallwood down to diameter over bark of 2 inches.								
Length.	Mid-diameters without bark.		Sectional area.	Volume.		Length.	Mid-diameters over bark.		Sectional area.	Volume.		Timber.	Smallwood.	Timber and Smallwood.
	At right angles.	Average.					At right angl .	Average.						
Feet.	Inches and decimals.		Sq. ft. and decimals.	Cub. ft. and decimals.		Feet.	Inches and decimals.		Sq. ft. and decimals.	Cub. ft. and decimals.		To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
	Nil.					10	4·8 4·8	*4·8*	*0·1257*	*1·2570*		*0*		*·341*
						13	3·0 3·0	*3·0*	*0·0491*	*0·6383*				
						23				*1·8953*				
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*		*0*

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 22nd August 1920.
Initials, A. B. C.

Sample tree number.	Species.	Age. (Years.)	Total height. (Feet.)	Length of shoot of last— years. (Ft. and decimals.)	Diameters at 4½ ft. At right angles. (Inches and decimals) O. B.	U. B.	Average. O. B.	U. B.	Corresponding basal area at 4½ ft. (Sq. ft. and decimals.)	Diameters at half total height. At right angles. (Inches and decimals.) Over bark.	Under bark.	Average. Over bark.	Under bark.	REMARKS.
A Outside.	Cedrus Deodara.	*34*	40	..	4·3 / 4·3	4·0 / 4·0	*4·3*	*4·0*	*0·1009*	2·6 / 2·6	2·4 / 2·4	*2·6*	*2·4*	Volume of cylinder = *4·0360*. Bark per cent. = *15*. Bark thickness at 4' 6" = *0·15*."

32 rings on stump, 5" above ground level.
Stump allowance = 2 years.

VOLUME MEASUREMENTS. Timber down to diameter over bark of 8 inches. Length. (Feet.)	Mid-diameters without bark. At right angles. (Inches and decimals.)	Average.	Sectional area. (Sq. ft. and decimals.)	Volume. (Cub. ft. and decimals.)	Smallwood down to diameter over bark of 2 inches. Length. (Feet.)	Mid-diameters over bark. At right angles. (Inches and decimals.)	Average.	Sectional area. (Sq. ft. and decimals.)	Volume. (Cub. ft. and decimals.)	FORM FACTORS. (To three places of decimals.) Timber.	Small-wood.	Timber and Small-wood.
	Stem.					*Stem.*				*Stem.*		
	Nil.				10	3·9	3·9	*3·9*	*0·0830*	*0·8300*	*0*	*·361*	
					17	2·6	2·6	*2·6*	*0·0369*	*0·6273*			
					27					*1·4573*			
	Branch.					*Branch.*				*Branch.*		
	Nil.					*Nil.*				*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28.   Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 20th May 1925.
Initials, X. Y. Z.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last 5 years.	Diameters at 4½ ft. At right angles.		Diameters at 4½ ft. Average.		Corresponding basal area at 4½ ft.	Diameters at half total height. At right angles.		Diameters at half total height. Average.		REMARKS.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
1	Cedrus Deodara.	*37*	63	5·9	12·0 / 11·3	10·3 / 10·3	*11·7*	*10·3*	*0·7467*	7·2 / 7·8	6·6 / 7·3	*7·5*	*7·0*	Volume of cylinder =*47·0421*. Bark per cent. =*13*. Bark thickness at 4′ 6″=*0·70″*.

35 rings on stump, 5″ above ground level.
Stump allowance = 2 years.

VOLUME MEASUREMENTS. Timber down to diameter over bark of 8 inches. Length.	Mid-diameters without bark. At right angles.		Mid-diameters without bark. Average.	Sectional area.	Volume.	VOLUME MEASUREMENTS. Smallwood down to diameter over bark of 2 inches. Length.	Mid-diameters over bark. At right angles.		Mid-diameters over bark. Average.	Sectional area.	Volume.	FORM FACTORS. Timber.	FORM FACTORS. Small-wood.	FORM FACTORS. Timber and Small-wood.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
10	10·4	9·9	*10·2*	*0·5675*	*5·6750*	10	7·3	7·9	*7·6*	*0·3151*	*3·1510*	*·257*	*·113*	
10	8·9	9·1	*9·0*	*0·4418*	*4·4180*	10	5·3	5·8	*5·6*	*0·1710*	*1·7100*			
6	7·8	7·8	*7·8*	*0·3319*	*1·9914*	9	3·0	3·0	*3·0*	*0·0491*	*0·4419*			
26					*12·0844*	29					*5·3029*			
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 20th May 1925. Initials, X. Y. Z.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last 5 years.	Diameters at 4½ ft. At right angles.		Diameters at 4½ ft. Average.		Corresponding basal area at 4½ ft.	Diameters at half total height. At right angles.		Diameters at half total height. Average.		REMARKS.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
2	Cedrus Deodara.	*37*	70	7·8	11·8 / 11·2	9·9 / 10·7	*11·5*	*10·3*	*0·7214*	7·8 / 7·6	7·7 / 6·8	*7·7*	*7·3*	Volume of cylinder =*50·4980.* Bark per cent. =*10.* Bark thickness at 4′ 6″=*0·60″.*

36 rings on stump, 3″ above ground level.
Stump allowance = 1 year.

VOLUME MEASUREMENTS.

Timber down to diameter over bark of 8 inches.

Length.	Mid-diameters without bark. At right angles.		Mid-diameters without bark. Average.	Sectional area.	Volume.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.
	Stem.				
10	10·0	10·3	*10·2*	*0·5675*	*5·6750*
10	9·0	9·1	*9·0*	*0·4418*	*4·4180*
13	8·0	7·7	*7·9*	*0·3404*	*4·4252*
33					*14·5182*
	Branch.				
	Nil.				

Smallwood down to diameter over bark of 2 inches.

Length.	Mid-diameters over bark. At right angles.		Mid-diameters over bark. Average.	Sectional area.	Volume.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.
	Stem.				
10	7·2	7·2	*7·2*	*0·2828*	*2·8280*
10	5·3	5·2	*5·3*	*0·1532*	*1·5320*
8	3·2	3·3	*3·2*	*0·0559*	*0·4472*
28					*4·8072*
	Branch.				
	Nil.				

FORM FACTORS.

Timber.	Smallwood.	Timber and Smallwood.
To three places of decimals.		
	Stem.	
·288	*·095*	
	Branch.	
0	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 20th May 1925.
Initials, X. Y. Z.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last 5 years.	Diameters at 4½ ft.				Corresponding basal area at 4½ ft.	Diameters at half total height.				REMARKS.
					At right angles.		Average.			At right angles.		Average.		
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
3	Cedrus Deodara.	*37*	60	5·0	9·1 / 9·3	8·5 / 8·5	*9·2*	*8·5*	*0·4617*	6·8 / 6·4	6·0 / 5·7	*6·6*	*5·9*	Volume of cylinder = *30·4722*. Bark per cent. = *20*. Bark thickness at 4' 6" = *0·35"*.

36 rings on stump, 2" above ground level.
Stump allowance = 1 year.

VOLUME MEASUREMENTS.												FORM FACTORS.		
Timber down to diameter over bark of 8 inches.						Smallwood down to diameter over bark of 2 inches.								
Length.	Mid-diameters without bark.			Sectional area.	Volume.	Length.	Mid-diameters over bark.			Sectional area.	Volume.	Timber.	Small-wood.	Timber and Small-wood.
	At right angles.		Average.				At right angles.		Average.					
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
10	8·6	8·4	*8·5*	*0·3911*	*3·9110*	10	7·3	7·4	*7·4*	*·2987*	*2·9870*	*·218*	*·235*	
9	7·4	7·4	*7·4*	*0·2987*	*2·6883*	10	6·6	6·5	*6·5*	*0·2304*	*2·3040*			
						10	5·0	5·1	*5·1*	*0·1418*	*1·4180*			
19					*6·6293*	8	3·3	3·2	*3·2*	*0·0559*	*0·4472*			
						38					*7·1562*			
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 20th May 1925.
Initials, X. Y. Z.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last 5 years.	Diameters at 4½ ft.				Corresponding basal areas at 4½ ft.	Diameters at half total height.				REMARKS.
					At right angles.		Average.			At right angles.		Average.		
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
4	Cedrus Deodara.	*35*	60	8·7	7·5 / 7·2	6·6 / 6·8	*7·4*	*6·7*	*0·2987*	4·5 / 4·6	4·2 / 4·2	*4·6*	*4·2*	Volume of cylinder = *17·9220*. Bark per cent. = *17*. Bark thickness at 4' 6" = *0·35"*.

33 rings on stump, 4" above ground level.
Stump allowance = 2 years.

VOLUME MEASUREMENTS.												FORM FACTORS.		
Timber down to diameter over bark of 8 inches.						Smallwood down to diameter over bark of 2 inches.						Timber.	Small-wood.	Timber and Small-wood.
Length.	Mid-diameters without bark.			Sectional area.	Volume.	Length.	Mid-diameters over bark.			Sectional area.	Volume.			
	At right angles.		Average.				At right angles.		Average.					
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
	Nil					10	7·0	7·0	*7·0*	*0·2673*	*2·6730*	*0*	*·411*	
						10	6·0	6·1	*6·1*	*0·2029*	*2·0290*			
						10	5·0	5·1	*5·0*	*0·1364*	*1·3640*			
						10	4·0	4·0	*4·0*	*0·0873*	*0·8730*			
						10	2·7	2·8	*2·8*	*0·0428*	*0·4280*			
						50					*7·3670*			
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. **Sample Plot Form No. 7.**

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Date 20th May 1925.
Initials, X. Y. Z.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last 5 years.	Diameters at 4½ ft. — At right angles.		Diameters at 4½ ft. — Average.		Corresponding basal area at 4½ ft.	Diameters at half total height. — At right angles.		Diameters at half total height. — Average.		Remarks.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
5	Cedrus Deodara.	*39*	50	5·3	6·4 / 6·5	5·8 / 6·1	*6·5*	*6·0*	*0·2304*	4·2 / 4·2	3·8 / 3·9	*4·2*	*3·9*	Volume of cylinder =*11·5200.* Bark per cent.=*14.* Bark thickness at 4′ 6″=*0·25″.*

38 rings on stump, 3″ above ground level.
Stump allowance = 1 year.

Volume measurements. — Timber down to diameter over bark of 8 inches. — Length.	Mid-diameters without bark. — At right angles.	Mid-diameters without bark. — Average.	Sectional area.	Volume.	Smallwood down to diameter over bark of 2 inches. — Length.	Mid-diameters over bark. — At right angles.		Mid-diameters over bark. — Average.	Sectional area.	Volume.	Form factors. — Timber.	Form factors. — Small-wood.	Form factors. — Timber and Small-wood.
Feet.	Inches and decimals.		Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.					*Stem.*					*Stem.*		
	Nil.				10	6·4	6·3	*6·4*	*0·2234*	*2·2340*	*0*	*·456*	
					10	5·3	5·3	*5·3*	*0·1532*	*1·5320*			
					10	4·2	4·2	*4·2*	*0·0963*	*0·9630*			
					10	3·2	3·1	*3·1*	*0·0524*	*0·5240*			
					40					*5·2530*			
	Branch.					*Branch.*					*Branch.*		
	Nil.					*Nil.*					*0*	*0*	

Note.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. I. 28. Sample Plot Form No. 7.

Measurement of Sample trees, U Bashahr, Division. Sample Plot No. 1, Date 20th May 1925.
Initials, X, Y. Z

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last 5 years.	Diameters at 4½ ft. At right angles.		Diameters at 4½ ft. Average.		Corresponding basal area at 4½ ft.	Diameters at half total height. At right angles.		Diameters at half total height. Average.		REMARKS.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
6	Cedrus Deodara.	*38*	51	3·7	5·0 / 5·2	4·5 / 4·6	*5·1*	*4·6*	*0·1418*	3·2 / 3·5	3·0 / 3·2	*3·4*	*3·1*	Volume of cylinder *=7·2318.* Bark per cent. *=17.* Bark thickness at 4′ 6″ *=0·25″*

37 rings on stump, 3″ above ground level.
Stump allowance = 1 year.

VOLUME MEASUREMENTS. Timber down to diameter over bark of 8 inches. Length.	Mid-diameters without bark. At right angles.		Average.	Sectional area.	Volume.	Smallwood down to diameter over bark of 2 inches. Length.	Mid-diameters over bark. At right angles.		Average.	Sectional area.	Volume.	FORM FACTORS. Timber.	Smallwood.	Timber and Smallwood.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
	Nil.					10	5·0	5·0	*5·0*	*0.1364*	*1·3640*	*0*	*·445*	
						10	4·2	4·1	*4·2*	*0·0963*	*0·9630*			
						10	3·3	3·6	*3·4*	*0.0631*	*0·6310*			
						7	2·6	2·5	*2·6*	*0·0369*	*0·2583*			
						37					*3·2163*			
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. R. 1 28. Sample Plot Form No. 7.

Measurement of Sample trees, U. Bashahr Division. Sample Plot No. 1, Dated 20th May 1925.
Initials, X. Y. Z.

Sample tree number.	Species.	Age.	Total height.	Length of shoot of last 5 years.	Diameters at 4½ ft. At right angles.		Diameters at 4½ ft. Average.		Corresponding basal area at 4½ ft.	Diameters at half total height. At right angles.		Diameters at half total height. Average.		REMARKS.
		Years.	Feet.	Ft. and decimals.	Inches and decimals.				Sq. ft. and decimals.	Inches and decimals.				
					O. B.	U. B.	O. B.	U. B.		Over bark.	Under bark.	Over bark.	Under bark.	
A Outside.	Cedrus Deodara.	*50*	75	7·9	12·3 / 13·6	11·4 / 12·5	*13·0*	*12·0*	*0·9218*	8·4 / 8·5	7·9 / 7·8	*8·5*	*7·9*	Volume of cylinder =*69·1350*. Bark per cent. =*14*. Bark thickness at 4′ 6″ =*0·50″*.

47 rings on stump, 6″ above ground level.
Stump allowance = 3 years.

VOLUME MEASUREMENTS. Timber down to diameter over bark of 8 inches. Length.	Mid-diameters without bark. At right angles.		Mid-diameters without bark. Average.	Sectional area.	Volume.	Smallwood down to diameter over bark of 2 inches. Length.	Mid-diameters over bark. At right angles.		Mid-diameters over bark. Average.	Sectional area.	Volume.	FORM FACTORS. Timber.	Small-wood.	Timber and Small-wood.
Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	Feet.	Inches and decimals.			Sq. ft. and decimals.	Cub. ft. and decimals.	To three places of decimals.		
	Stem.						*Stem.*					*Stem.*		
10	12·3	11·5	*11·9*	*0·7724*	*7·7240*	10	7·1	6·9	*7·0*	*0·2673*	*2·6730*	*·332*	*·063*	
10	11·3	11·4	*11·4*	*0·7089*	*7·0890*	10	5·1	4·8	*5·0*	*0·1364*	*1·3640*			
10	9·9	9·5	*9·7*	*0·5132*	*5·1330*	7	3·1	3·0	*3·0*	*0·0491*	*0·3437*			
8	8·2	8·4	*8·3*	*0·3758*	*3·0064*									
						27					*4·3807*			
38					*22·9514*									
	Branch.						*Branch.*					*Branch.*		
	Nil.						*Nil.*					*0*	*0*	

NOTE.—Entries made in the office are shown in italics to distinguish them from those recorded in the field.

F. B. I. 140. Sample Plot Form No. 11.

Classification and grouping of diameters.

Sample Plot No. 1, U. Bashahr Division. Species, Cedrus Deodara. Initials, M. N. O. Dated 2 st October 1920.

D. B. H. Class.	Main Crop, 1920.
14	// = 2
13	~~////~~ = 5
12	~~////~~ ////= 9
11	~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~ //// = 34
10	~~////~~ ~~////~~ ~~////~~ ~~////~~ // = 23
9	~~////~~ ~~////~~ ~~////~~ ~~////~~ // = 22
8	~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~ / = 26
7	~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~ / = 26
6	~~////~~ ~~////~~ /// = 13
5	~~////~~ / = 6
4	~~////~~ / = 6
	Grand total . 172

	Grouping.
A.	Area of plot.—0·162.
B.	Total number of diameters per acre.—1062=50+50+50+50+100+100+100+100+200+262.
C.	Number of diameters 8″ and over.— 747=50+50+50+50+100+100+100+100+147.
D.	Number of diameters under 8″.— 315= 53+262.
E.	Groups for 1 acre.— 1062=50+50+50+50+100+100+100+100+147+315.
F.	Groups for plot of 0·162 acre.— 172= 8+ 8+ 8+ 8+ 16+ 16+ 16+ 16+ 25+ 51.

Notes.

F. R. I. 140. Sample Plot Form No. 11.

Classification and grouping of diameters.

Sample Plot No. 1, U. Bashahr Division. Species, Cedrus Deodara. Initials, R. S. T.
Dated 25th October 1926.

D. B. H. Class.	Main Crop, 1925.	
15	|	= 1
14	|||	= 3
13	𝍸 𝍸 |||	= 13
12	𝍸 𝍸 𝍸 𝍸 ||	= 22
11	𝍸 𝍸 𝍸 𝍸 𝍸 ||	= 27
10	𝍸 𝍸 𝍸	= 15
9	𝍸 𝍸 𝍸 𝍸 |	= 21
8	𝍸 𝍸 𝍸 𝍸 𝍸	= 25
7	𝍸 𝍸 ||||	= 14
6	𝍸 𝍸 |	= 11
	Grand total .	152

	Grouping.
A	Area of plot 0·162.
B	Total number of diameters per acre.—938=50+50+50+50+100+100+100+100+200+138.
C	Number of diameters 8″ and over per acre.—784=50+50+50+50+100+100+100+100+184.
D	Number of diameters under 8″ per acre.—154= 16+138.
E	Groups for 1 acre.— 938=50+50+50+50+100+100+100+100+184+154.
F	Groups for Plot of 0·162 acre.— 152= 8+ 8+ 8+ 8+ 16+ 16+ 16+ 16+ 31+ 25.

Notes.

F. R. I. 140. Sample Plot Form No. 11.

CLASSIFICATION AND GROUPING OF DIAMETERS.

Sample Plot No. 1, U. Bashahr Division. Species, Cedrus Deodara. Initials, R. S. T.
Dated 25th October 1926.

D. B. H. Class.	Subsidiary Crop, 1925.
12	// = 2
11	// = 2
9	// = 2
8	/// = 3
7	// = 2
6	/ = 1
5	/// = 3
4	~~////~~ = 5
	GRAND TOTAL . 20

	GROUPING.
A	Area of Plot.—0·162.
B	Total number of diameters per acre.—124=50+50+24.
C	Number of diameters 8″ and over per acre.—56=50+6.
D	Number of diameters under 8″ per acre.—68= 44+24.
E	Groups for 1 acre.— 124=(50+6)+(44+24).
F	Groups for Plot of 0·162 acre.— 20=(8+1)+(7+ 4) = 9+11.

Notes.

F. R. I. 140. Sample Plot Form No. 11.

Classification and grouping of diameters.

Sample Plot No. 1, U. Bashahr Division. Species, Cedrus Deodara.
Initials, R. S. T. Dated 26th October 1926.
1920 back check with 1925.

D. B. H. Class.	Main Crop, 1920.	
14	//	= 2
13	~~////~~	= 5
12	~~////~~ ////	= 9
11	~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~ ~~////~~ /	= 31
10	~~////~~ ~~////~~ ~~////~~ ~~////~~ //	= 22
9	~~////~~ ~~////~~ ~~////~~ ~~////~~	= 20
8	~~////~~ ~~////~~ ~~////~~ ~~////~~ ////	= 24
7	~~////~~ ~~////~~ ~~////~~ ~~////~~ ////	= 24
6	~~////~~ ~~////~~ /	= 11
5	////	= 4
	Grand total .	152

Grouping.

A	Area of plot 0·162.
B	Total number of diameters per acre.—938=50+50+50+50+100+100+100+100+200+138.
C	Number of diameters 8″ and over per acre.—784=50+50+50+50+100+100+100+100+184.
D	Number of diameters under 8″ per acre.—154= 16+138.
E	Groups for 1 acre.— 938=50+50+50+50+100+100+100+100+184+154.
F	Groups for Plot of 0·162 acre.— 152= 8+ 8+ 8+ 8+ 16+ 16+ 16+ 16+ 31+ 25.

Notes.

F. R. I. 140. Sample Plot Form No. 11.

CLASSIFICATION AND GROUPING OF DIAMETERS.

Sample Plot No. 1, U. Bashahr Division. Species, Cedrus Deodara.
Initials, R. S. T. Dated 26th October 1926.
1920 back check with 1925.

D. B. H. Class.	Main Crop, 1920—*contd.*	
11	///	= 3
10	/	= 1
9	//	= 2
8	//	= 2
7	//	= 2
6	//	= 2
5	//	= 2
4	~~////~~ /	= 6
	GRAND TOTAL .	20

GROUPING.

A	Area of Plot.—0·162.
B	Total number of diameters per acre.— 124 = 50+50+24.
C	Number of diameters 8″ and over per acre.—56 = 50+6.
D	Number of diameter under 8″ per acre.—68 = 44+24.
E	Groups for 1 acre.— 124 = (50+6)+(44+24)
F	Groups for Plot of 0·162 acre.— 20 = 9+11.

Notes.

APPENDIX V.

Tree Classification and Thinning Scale for Sample Plots.

(*Cf.* The Indian Forest Records, Vol. XV, Part I, 1930, on which the following is based with the few further sub-divisions required for research work in contrast with divisional requirements).

A. Tree classification.

The trees forming an even-aged high forest may be classified with reference to their relative height and development, according to the following scheme :—

I.—DOMINANT TREES. (D); including all trees which form the uppermost leaf canopy and have their leading shoots more or less free. These may be sub-divided according to the position and relative freedom of their crowns into :—

(*a*) PREDOMINANT TREES (D1) comprising of all the tallest trees which determine the general top level of the canopy and are free from vertical competition.

(*b*) CODOMINANT TREES (D2) comprising of the next tallest trees which have their leaders quite-free but only attain about $\frac{7}{8}$ of the average height of D1.

Both the subclasses may further be classified according to their vigour and soundness or otherwise into :—

(*a*) Trees with normal crown development and good stem form.
(*b*) Trees with defective stems or crowns, e. g. :—
1. Trees with crown space cramped by neighbouring trees.
2. Badly spaced old advance growth.
3. Trees with forked leader and similar defects.
(*c*) Trees with very defective stems or crowns, *i.e.*, with the same defects as (*b*) to such an extent that they are of little or no present va'ue or promise.
(*d*) Whips.

Trees with very thin bole and very restricted crown incapable of existence without the support of the neighbouring trees.

II.—DOMINATED TREES (*d*), which do not form part of the uppermost leaf canopy, but the leading shoots of which are not definitely over-topped by the neighbouring trees. Their height is about $\frac{3}{4}$ that of the tallest trees—

(*a*) Trees with normal crown development and good stem form.
(*b*) Trees with defective crowns or stems.

III. SUPPRESSED TREES (s), which reach only about $\frac{1}{2}$ to $\frac{2}{3}$ of the height of the best trees, with their leading shoots definitely over-topped by their neighbours or at least shaded on all sides by them. A small tree of height typical of suppressed trees standing with its leader free in a chance gap should not be classed as D or d.

IV.—DEAD AND MORIBUND TREES (m).

This class also includes bent over and badly leaning trees usually of the whip type.

V.—DISEASED TREES (k)* including those which are infected with parasites to such an extent that their growth is seriously affected or that they are a danger to their neighbours—

(*a*) Dominant.
(*b*) Dominated and suppressed.

In allotting trees to their canopy and crown class, it will often appear doubtful whether a certain tree should go to D1 b or D2a, the height being on the border line between the two canopy classes and the crown being small for D1 but normal for D2. This is not of much importance, as in thinnings the two types D1b and D2a would usually be considered together for removal, but decision is facilitated if any tree likely soon to descend in canopy class is relegated to D2 and any likely to keep up, only falling off in crown class, is included in D1.

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* The symbol k is proposed as suggestive of canker.

B. Thinning.

Thinnings are defined in the Glossary of Technical Terms for use in Forestry as 'the removal of excess stems from a crop beyond the sapling stage with the object of diminishing adverse competition and affording more light and space.'

The sapling stage is left when the lower branches begin to dry, generally about when the breast height diameter of the dominant stems reaches 4″ in a fairly closed crop. The essential point about a thinning, however, is that no lasting interruption of the leaf canopy is created.

Thinnings are mostly concerned with the removal of the following types of tree usually in the order given :—

(i) Dead and dying trees.
(ii) Trees which have been definitely left behind in the struggle for existence.
(iii) Trees which are getting left behind.
(iv) Diseased trees.
(v) Misshapen trees.
(vi) Trees with poorly developed crowns or boles.
(vii) Trees with good crowns and boles which are restricting the development of still better trees.

Of these, (i) and (ii) comprise trees the removal of which has a minimum of influence (at least direct influence) on the development of the rest of the crop, and so their removal might well be excluded altogether from the term thinning, were it not for the fact that it is most convenient to include all stems removed under a single term. It will be seen that the dominated trees (iii) and to a less extent the suppressed trees (ii), are sometimes retained and sometimes removed under different types of thinning applicable to different species or under different conditions, and in practice, thinnings which are to influence the increment of the trees retained generally fall in the first place on the inferior trees grouped under (iii), (v) and (vi). Only the heavier forms of thinning remove many of the good stems (vii), and only the heaviest of all reduce the number of stems which are satisfactory in all respects. In all cases even distribution of stems is aimed at.

* * * * * *

Kind of Thinning.—There are two main principles according to which thinnings may be done. The first aims at the gradual improvement of the average dominant trees present without making appreciable inroads among the dominants themselves, *i.e.*, the fellings fall mainly on the dominated and suppressed stems, primarily the bigger of them which are more or less retarding the further development of the neighbouring dominants. The suppressed trees and smaller dominated trees are usually removed at the same time, but it is possible with the heavier intensities of this kind of thinning to make a qualification retaining them as soil cover, or as insurance against casualties among the larger trees standing over them or simply because it is not worth spending money on felling them. This kind of thinning is known as Ordinary thinning (German, *Niederdurchforstung*, French, *Eclaircie par le bas*).

The second aims at giving a maximum of help to a restricted number of the best stems; such help *requires primarily the removal of competing dominant trees* as soon in the life of the crop as crown differentiation has progressed far enough to permit of it. The dominated and suppressed trees are then retained to maintain the soil cover and utilise such of the increased light and space as the selected best stems cannot deal with for the time being. This kind of thinning is known as a Crown thinning (German, *Hochdurchforstung*, French, *Eclaircie par le haut*).

Intensity of thinnings.—Subject to the above remarks, the kinds and intensities of thinnings to be distinguished, and the trees to be removed under the several grades of thinnings are as follows :—

I. Ordinary thinning :—

(1) Light thinning (A grade).—V, IV, and III classes of trees.
(2) Moderate thinning (B grade).—V, IV, III, II (b), D2 (d) and D1 (d) and occasionally a D1 (c) classes of trees.

(3) **Heavy thinning** (C grade).—V, IV, III, D1 (d), D2 (d), and gradually all II D2 (b) and D_2 (c) and part of D_2 (a) and D_1 (c) classes of trees.

(4) **Very heavy thinning** (D grade).—V, IV, III, D1 (d), D2 (d) and gradually all II D2, D1 (c), D1 (b) and part of D1 (a) classes of trees.

II. Crown thinning :—

(1) Light crown thinning (L. C. grade).—V, IV, D2 (d), D1 (d), part of D2 (a), D2 (b), D2 (c) and D1 (b) and a great part of D1 (c) and some D_1 (a) classes of trees.

(2) Heavy crown thinning (H. C. grade).—V, IV and all D2 and D1 hindering elite stems.

NOTE.—V, IV and III may be left if their removal is of no economic or hygienic value.

CHAPTER XI.

SAMPLE PLOTS, CONTD., THINNING RESEARCH.

Thinning investigations (7, Item 14) are a special case of the study of crop increment (in all its factors) with attention directed to :—

1. Total volume production.
2. Total wood production in timber down to any selected minimum dimensions.
3. Height growth.
4. Taper and shape of the trees.
5. The quality of the timber produced with special reference to relative freedom from branches and knots.

It is convenient to consider separately the following five aspects, of which all but the last are primarily concerned with pure crops.

1. Thinning in pole and tree crops. (Section (i), below).
2. Thinning in short rotation coppice crops (Section (ii), p. 228).
3. Early thinnings of young natural regeneration (Section (iii), p. 230).
4. Early thinnings of young plantations (Section (iv), p. 232).
5. Thinning in mixed crops. (Section (v), p. 233).

(I) Thinning in Pole and Tree Crops.

A. Object of the investigations.

It is required to determine for each species, what thinning regime is suitable for application in ordinary divisional practice from the point of view of the general or local objects of management such as are listed at the head of this chapter. In this section it is assumed that the thinnings are to be done in plantations, and in the more regular parts or groups of natural crops which may or may not have been thinned hitherto.

B. Factors involved.

1. *Kind of thinning.*—Only Ordinary and Crown thinnings have to be considered. The latter are usually considered to be applicable to species of at least moderate shade bearing constitution, as the fundamental principle of the method is the retention in healthy condition of the lower canopy layers : the former can be applied to all species, but particularly to light demanders. Practical considerations in divisional practice (unremunerative fellings of small-sized stems) may necessitate the retention of more or less dominated and suppressed trees when under the prescribed scale they should be removed, but this is not of importance provided the trees of the future crop get the growing space prescribed for them.

It should be noted that Crown thinning can only be introduced early in the life of a crop since the lower canopy layers have to be retained.

2. *Intensity (Grade) of thinning.*—The standard scale defined in terms of standard tree classes (by canopy layers and crown classes) is given in Appendix V, p. 217. To ensure continuity, suggestions are made below for a numerical check to be applied *within the limits allowed by purely silvicultural considerations* (cf. p. 226).

3. *Frequency of thinning.*—It is accepted that a thinning cycle of less than 10 years is neither necessary nor desirable, and further, that one of 10 years is or will become feasible in all divisions as management becomes more intensive.

Some of the most valuable European researches (*e.g.*, those of Flury (*12*, p. 82) in Switzerland) have been carried out with a 5 years' cycle, but yield tables almost invariably provide for intermediate yields every 10 years.

At the same time, it is to be realised that the interval may well vary with the age of the crop, becoming longer for older crops which close up more slowly and suffer less from the effects of under-thinning than do young crops in which height and crown growth is still rapid. Practical considerations limit the thinning cycle to a minimum of 10 years in almost all cases.

4. *Crown Development.*—The extent and shape of the crown depends to a large degree on the thinning treatment. Its importance lies in its influence both on the diameter increment and the form of the individual tree, and on the absolute and relative extent of clean bole yielding high quality timber. The field measurement and the evaluation of differences of measurements provide the most difficult problems in thinning research.

C. *Methods of investigation.*

The standard sample plot of Chapter X fulfils the essential requirements for thinning research, but a number of additional factors call for consideration.

If an adequate number of plots could be laid out, so that complete sets sufficient for yield table compilation were available, each treated under one recognised thinning procedure, this would be the ideal solution. Each set would be worked up independently and end results compared, the only problem—by no means settled for that matter—being the determination of what figures are comparable as between the two sets. This is the position in Europe accounting for the widely different yield tables, for example, for oak as compiled by Schwappach (*13*, p. 24) heavier thinning and Wimmenauer (*14*, p. 261 lighter thinning), and for spruce as reproduced on p. 224 or as recently compiled by Gehrhardt (*16a*).

Pending the attainment of this ideal, valuable information can be obtained from pairs and sets of comparable plots differently treated (cf. Sample Plot Field Rule 7, p. 114), and in some ways deductions from the results with such plots are on firmer ground than those derived from the comparison of average data obtained under the preceding method where the actual compilation may introduce new factors. Moreover, with time, the data from the sets of plots will accumulate and permit of the application of the compilation method also.

Experience has shewn the difficulties of ensuring continuity of treatment at successive thinnings, particularly when plots are not adjoining. A procedure has been devised, based on the relation between number of stems and mean diameter with due regard to quality class of locality, for checking the number of stems removed at each thinning of the prescribed kind and intensity within the silviculturally permissible limits of the latter.

Relatively small differences (especially as regards clean bole) being in question, periodic measurements of the same standing sample trees in the plots acquire an enhanced value and should be obtained whenever possible.

• A method of assessing tree quality is required. Apart from an expert utilisation officer's appraisals, data are required beyond what are ordinarily collected on sample trees (cf. p. 121) as listed in Field Rule 6 below, and it has been suggested in the foregoing chapters that they should be collected on all sample trees as a routine measure.

D. Results obtained in other countries.

Switzerland.—P. Flury, (*12*) (Ordinary thinnings), and A. Engler (Crown thinnings, mainly on spruce and beech).

A translation of Flury's summarised conclusions with Engler's (*8*) further interpolated, is as follows :—

Basal Area and Volume Increment.

1. From the point of view of increasing increment in basal area and volume, the best grade for young and middle-aged spruce and beech crops of all qualities is between B and C, nearer C (Crown thinning comes nearest to C).

2. In the latter half of the rotation, the grade should be raised.

3. The greater increment frequently found with grade D is more in the lower parts of the stems so that the basal area is increased relatively more than the volume.

4. Grade D particularly favours the production of more small branchwood, whilst production of the more valuable wood over 7 cm. diameter compares unfavourably with C and B.

5. Young crops which on account of delay in thinning or similar causes have fallen off in growth, are best severely thinned (Grade C) at once, as they recover most quickly thus.

Diameter Increment.

6. Thinning of all grades benefits primarily the diameter classes close round the mean diameter

7. Large stems shew a more pronounced diameter increment with C and D (and crown thinning than with B and A, but only on the single stem, whilst the total increment is much the same for all grades.

8. In the main crop, spruce shews the highest percentage diameter increment in the upper diameter classes, and beech in the lower. With beech, Grades C and D do not raise the increment of the higher diameter classes much more than does B.

9. In the subsidiary crop, diameter increment of spruce is raised by C and still more by D, whilst B and A hardly make any difference.

10. For beech, the increment of the subsidiary crop is greater for all grades than for spruce, and is also more enhanced by C and D than by B and A.

Height Increment.

11. The current annual height increment with C and D grades is greater than with B and still more so than with A. (Crown thinning resembles C and D.)

12. Grade C is the most favourable with regard to height increment.

13. With Grade A, height increment remains definitely behind.

Volume of the Crop wood over 7 cms. diameter under bark.

14. The volume of the main crop is never reduced with any grade below the volume of the last measurement.

15. The biggest main crop volume is obtained sometimes with C sometimes with B (Crown thinning resembles C).

Treatment of stands approaching maturity.

16. Crops on entering the last third of the rotation age should be so treated that real thinnings are no longer required and so practically the whole increment goes to the main crop.

17. Herein lies the favourable effect of early and thorough thinnings (apart from the higher thinning yields), which give maximum utilisation of the possible increment laid down on a main crop with a large volume in big assortments—this with a relatively short rotation, or at least without raising the rotation.

Timber Production.

18. Branchiness increases with higher grades of thinning. There is little difference between B and C, but D results in much more branchiness than C.

19. Maximum timber is obtained with B to C, with a tendency to C with increasing age.

Financial Returns.

With uniform grading and current prices, the return with different thinnings stand in the following order, fuel sales favouring ordinary thinning considerably :—

20. Main crop. (1) D, (2) C, (3) B and Crown, (4) A.

21. Total crop. (1) D, (2) C and Crown, (3) B, (4) A (or equal to B).

Swiss foresters generally have thinned A and B, and should now advance to B and C.

For measuring, a 20 metre telescopic ladder of fire escape type has been used since 1895.

218 spruce plots thinned 2-4 times and 124 beech thinned 2-3 times were available, and actually the main set was a series of 4 for each species demarcated and thinned in 1889, when 28 years old. These were supplemented by one other complete series and various pairs, 30 spruce and 22 beech in all, mostly B and C. Ages at the start were 19 to 50 years for spruce, and 20 to 105 for beech.

Germany. Conclusions drawn are generally similar to those for Switzerland. Reinhold (*15*) and Gehrhardt (*6*) have summarised results in recent years, and directed attention to the importance of the concentration of as much of the increment as possible on selected best stems with a view to rapid production of large sized timber without undue deterioration in quality, branchiness and low form factor. The following tables in which the data for crops of spruce 100 years old with a main crop volume (down to 7 cm. diameter) of 800 cubic metres per hectare (= 11400 c.ft. per acre) have been collected from all published sources, illustrate the range to be dealt with on soils of approximately equal quality.

Number of stems per acre.	Mean Height Ft.	Mean diameter Ins.	Author's Quality Class.	Authority.
334	88·6	7·7	II·7	Flury in mountains.
286	103·3	8·3	I·5	Keuper in Mid Frank.
273	91·6	8·4	II	Gutenberg.
265	65·6	8·5	II	Lorey.
194	103·7	9·5	I·4	Gehrhardt.
160	109·2	10·1	I	Schwappach (10500 c.ft.).
150	111·5	10·7	I	Grundner.
50	121·4	16·0	I	Gehrhardt (Rapid growth with 9700 c.ft.).

Gehrhardt's latest tables for spruce (*16a*) are threefold, with separate figures for three types of thinning.

Sweden.—From 269 thinning plots of *Pinus sylvestris* from 1902 onwards, and 140 for *Picea excelsa,* the following deductions have been drawn (*7*):

1. Thinnings over 20-25 years have raised the total volume increment by 12-20 per cent. over the unthinned controls.
2. Crown thinnings are generally not quite so effective as ordinary thinnings in this respect.
3. D grade thinnings are not so heavy as to cause any falling-off of increment.

America.—With *Pinus Strobus* plots (*18*), the same conclusions are reached as in Sweden. Methods and a good general bibliography have been given by Barret and Righter. (*19*).

NOTES.—In practice, a single grade will not be applied to extensive areas, but one will allow for the varying character in one of the same crop by varying the grade similarly. The results summarised above also cannot form the basis for fixed rules for tending, but they serve in an objective way as an experimentally determined basis for a rational thinning technique.

E. Field work.

Investigations can best be carried out in permanent sample plots as described in Chapter X. The following additional notes should be read with the corresponding sections of that chapter.

(1) *Selection of plots.*—To minimise quality class differences, the plots of a set should be as close together as the crop and ground permit. Pairs or sets of plots to give results of maximum utility, must at the start be comparable within acceptable limits. When the lightest grade of thinning to be applied has been done in all the plots of the set, basal area per acre should not ordinarily vary more than 10 per cent., number of stems more than 20 per cent., and average height more than 15 per cent. Whilst rigid adherence to these figures may not be practicable, the comparison should be made.

(2) *The surround.*—Whenever possible, the plots of a set should be separated by a strip of approximately two to three crown widths, so that the thinning in one plot will not affect the growing space of trees in the other. That this is not possible should not however prevent pairs or sets of plots being laid out.

(3) *Demarcation.*—Each plot of a set is independent and so separately demarcated. If no separating strip can be excluded, one, two or more corner posts may be common to adjoining plots. Each plot a set should have its own serial number.

(4) *Thinnings.*—In all plots which form part of special thinning sets, and as far as possible, in all plots, the number of stems which will remain after thinning and their mean diameter (the diameter corresponding to mean basal area) should be compared with the number which should be present for that diameter on the quality class concerned (determined by the height-age relation) according to the published yield tables. The trees under consideration for removal under the prescribed scale of thinning are listed before felling and are re-examined with a view to the final retention or removal of trees concerning which difference of opinion is possible, the test being that C-grade should shew 110-90 per cent. of the published yield table figures, D-grade 90-70 per cent and a (research) E-grade only 70-50 per cent. It is

emphasised that the silvicultural description of the thinning grade given in Appendix IV must be adhered to, and this numerical check is only to be applied to the 'border-line' trees; it is particularly useful as a check that the initial and desired difference between the plots of a set is maintained. Anomalies will be encountered in older crops which have grown up in a crowded condition without thinnings.

The E grade ordinary thinning mentioned above is probably heavier than desirable in practice, taking all trees possible without causing lasting gaps in the canopy—somewhat like HC. but without retention of the lower canopy classes—but is required in research work for determining the optimum intensity.

Quality class is determined by the relative position of the crop age/crop height point on the yield table curves by quality classes. When number of stem per acre of given diameter varies considerably with quality class, fractional quality is required, the limits for each quality being subdivided into 10 units above and 10 below the average.

The removal of additional trees will alter the mean diameter of the plot, and therefore the corresponding yield table number of stems per acre. If more trees over the original mean diameter are taken, this number per acre will rise and the percentage stocking will fall; if the trees taken are less than the original mean diameter the yield table number will fall and the percentage stocking may or may not be altered.

Ex. 38. *Sample Plots in Pinus excelsa in Chakrata division, United Provinces.*

Plot Number.	Crop Height.	Age.	Quality class.	Crop diameter.	Number of stems.	Percentage to yield table.	Thinning grade.
	ft.	yrs.		ins.		percent.	
68	83	54	0·0 I	11·0	219	82	D
69	84	55	1·9 II	11·0	198	73	E
70	85	57	1·9 II	10·9	263	99	C

In the case of plantations, age may be substituted for diameter if preferred (usually for teak). (Cf. Proc. Silv. Conf. 1929, p. 218.)

Crown thinning is not included in the above procedure: it can rarely be introduced in crops which have not been thinned from an early age unless they have come up in very open canopy. Where the retention of the few suppressed or pronouncedly dominated lower canopy trees is held desirable (as usually with deodar), they should be excluded from the above described calculations.

(5) *Selection of sample trees.*—In thinning investigations, great advantages are obtained by measuring standing sample trees in the plot which can again be measured at later dates (Engler considered this absolutely necessary).

(6) *Measurement of sample trees.*—In addition to the usual measurements, the following are necessary:—

(*a*) Length of crown (as average between lowest limit of green crown and point where green crown is developed on all sides).

(*b*) Length up to any customary diameter limit.

(*c*) Stem timber form factor up to that limit.

(*d*) Form quotient data (*cf.* General Rule 23*g*, p. 11).

(7) *Records.*—The same records should be maintained as for other permanent sample plots, but a set file consisting of Situation Map, Description Form 2 and Subsequent History Form 2 *a*, should be opened for each set of adjoining plots, recording all information common to both or all plots, and all comparisons between

the plots ; the actual plot file should then only give the information peculiar to it, i.e., absolute as opposed to comparative data, duplication being unnecessary.

(8) *Miscellaneous.*—The different degrees to which the canopy is opened in the plots provide an excellent opportunity for collection of data concerning the associated vegetation with a view to analysing out the effect of light intensity from that of quality class.

F. Computation.

(a) Comparison as yield tables.

The plot data are calculated on the standard lines. When sufficient data accumulate, they can be compiled separately for each thinning grade, quality class limits being determined from the initial height/age data for all plots.

(b) Comparative study of sets of plots.

1. *Mortality* from all causes can be compared.

2. *Average dimensions* (diameter, height, standard timber volume, commercial timber volume. etc.) can be worked out for each plot for any of the following selections of trees.

(i) All trees standing.
(ii) All dominant trees.
(iii) That number of trees (counting from the biggest diameters downwards) in all plots of a set which is finally standing in the most heavily thinned plot.
(iv) The same basal area in all plots as is finally standing on the most heavily thinned plot (Reinhold).
(v) The largest x stems per acre in each plot. (x might well be taken as the number expected to be standing at maturity).
(vi) Trees of the same initial diameter in all plots (Flury).

The selection made will depend on the species and local conditions. Where production of large timber is the first requirement, (v) probably gives the best picture, whilst where total production is also important, or medium sized timber is also saleable with profit, (iii) or (iv) are preferable. At the same time, (vi) is most useful in bringing out differences in development. All these methods may, however, become misleading as they divorce the tree from the crop.

3. *Total basal area* at each stage with its increment provides a simple basis of comparison.

4. *Total production* can also be compared in several ways.

(i) Total standard timber and smallwood volume.
(ii) Total standard timber volume.
(iii) Total commercial timber volume (assessed on each stem, generalised from measured sample trees, or measured down to an arbitrary diameter limit).
(iv) As any of foregoing, but classified into several assortments which may be assigned absolute or relative monetary values (Schwappach thus used four timber grades, pit-wood, and three fuel classes).

In all cases, fellings required to bring about initial comparability are of course excluded.

It has also been proposed that when commencing an investigation, one should record by their serial numbers for the unthinned control plot of a set, which trees would remain standing after a thinning corresponding to each of the other thinned plots, and in making comparisons, consider those trees only.

(II) Thinning in Short-rotation Coppice Crops.

A. Object of investigations.

The aims in view will be the same as in the previous sub-chapter, but maximum sustained volume outturn is commonly the chief object, subject to the production of an adequate proportion of the type of poles in local demand.

B. Factors involved.

1. *The number of shoots retained per stool, and the age at which the reduction is made to an accepted optimum (3, 2, or 1).*

This factor is best studied in the first place on individual stools, particularly where coppice of mixed species is in question. It is concerned rather more with specific characters than with those of crops, and so is dealt with in the Experimental Manual, *q.v.* p. 113. At the same time when opportunity offers, it may also be studied as a crop problem on the lines described below.

2. *The interaction of species in a mixture.*

So many variables are involved in this problem that it is impossible to lay down a procedure to be followed, but it is suggested that this too should first be investigated as a tree problem on selected stools before crop studies are attempted. See further p. 233.

3. *The ages at which thinnings are made and the nature of the thinnings applied.*

Precisely the same considerations apply as for high forest, cf. p. 221 above. The standard thinning scale is superimposed on and to some extent combined with the reduction of the number of shoots per stool. Usually only 1-3 thinnings are in question, but the exact age at which they are made is often of importance (7, p. 237).

C. Methods of investigation.

(*a*) It must first be repeated that for rotations of 30 years or over, the full sample plot procedure should be applied as described in Chapter X and the foregoing sub-chapter.

This has been done in the case of the published yield tables for *Shorea robusta* coppice which extend to an age of 60 years.

The only difference is that when the plots reach the age at which it is decided to clearfell them, complete measurement of every tree is possible, giving a valuable check on the accuracy of the method and its application.

(*b*) For short rotations of 15 to 30 years, the full procedure is equally applicable, but it is often possible to dispense with periodic volume determinations of the standing crop in view of the fact that a complete measurement will be possible at

the final clearfelling at the end of a relatively short period of years: all intermediate yields are completely measured up in the same way. Total production (by assortments if necessary) and mean increment are thus determined, but not current increment. Periodic callipering of the standing crop in the usual way will however give current periodic basal area increment.

D. Past Experience.

France.—Experiments by E. Mer (*20*, p. 141) showed that the removal of the smaller shoots has a definitely beneficial effect on the growth of the remainder in d.b.h. and volume, with consequent increase of money yield. He found evidence that there is probably an optimum number of shoots per stool varying with species and locality (4 shoots in his experiments). *Jolyet* (*21*, p. 111) recommends restriction of thinning to the dominant poles.

India.—With *teak*, it was found by Edie (*22*) that removal of the small shoots had very little effect on the growth of the dominant shoots, but it appears that the experiments were made in very open crops such that new small shoots promptly replaced those cut, a reaction which might conceivably reduce the growth on the dominant shoots. Season of cutting is also probably of importance.

With *sal* (*23*), yield tables have been published for coppice growth with thinnings in the 5th and 10th years and thereafter every ten years. The tables differentiate two qualities A and B, and go up to 60 years. No comment is made on the effect of different methods of thinning.

E. Field Work.

The procedure is the same as is prescribed for sets of thinning plots in poles and tree crops on p. 225 to p. 227. The points to which special attention should be given in this type of growth are as follows:

(1) *Selection of plots.*—Plots should be as close together as the crop and ground permit. They will usually be laid out at the age when the first real thinning is due, and it should be seen that the stocking is of equal density and similar distribution in all the plots of a set, that the stools themselves are comparable as between plots in size and conditions; and, in the case of mixed crops, that the variation in the mixture is not so great as to be likely to confuse the issue, taking into consideration the known characteristics of the component species. Average height of dominant stems should not differ more 15 per cent. in the plots of a set. Age of shoots should be identical. Basal area before thinning should not vary more than 10 per cent.

(2) *Surround.*—A surround is rarely necessary for the purpose of restricting the effect of the conditions of one plot on the growth of another, but a common surround to a set of plots should be laid out for purposes of protection.

(3) *Measurement of standing crop.*—The sample plot rules 29-39 apply for cross marking and numbering (cf. p. 118), the latter being usually unnecessary. Periodic remeasurements are necessary for purposes of check, at periods approximating the standard five years as selected for the particular case (and laid down in Form 2) to fit in with the thinning cycle under investigation.

(4) *Thinnings.*—The grades of thinning (including the more or less mechanical reduction of number of stems per stool) which should be applied, and the ages at which they should be made to attain the objects of managements, should first be estimated from any available information. The limits between which the optimum in both respects probably lies should also be estimated, and a selection made of combinations of grade and age to cover the whole range with a reasonable number of plots—say 20 at the outside. In making thinnings in crops as regular as short rotation coppice, number of dominating stems at the known age forms a quite satisfactory basis of thinning. C grade may again be taken as standard, and the figures suggested on p. 225 for the other grades will probably prove suitable for use as checks on the silvicultural description of the grade.

(5) *Measurement of thinnings.*—According to local conditions the ordinary sample tree procedure may be followed, or the total volume removed may be measured as numbers of pieces of standard grades and/or as total stacked volume, with average solid volume for the former and the necessary conversion factors to solid volume or dry weight for the latter. Special care is obviously required that all stacking is uniform, and in all cases, the measurement procedure should be precisely the same for the thinnings as for the final yield on clearfelling.

(6) *Selection and measurement of sample trees.*—With the small dimensions here involved, the necessary measurement can often be taken on standing sample trees, but usually there is no difficulty in obtaining the necessary stems from the thinnings, at least with the heavier grades.

F. *Computations.*

The actual computations for coppice crops differently thinned introduce no new principles, but comparisons of differences in total volume production, and differences in the assortments in which a given volume may be produced, are difficult, as with high forest. The only satisfactory way of assessing the comparative results of two thinning procedures when the question of assortments is involved—as it always is except where the forest is worked entirely for fuel—is to assess the monetary value of the yields obtained. Even if generally acceptable values for the several assortments concerned cannot be obtained, fairly reliable ratios usually can be, and are equally serviceable for the purpose here in view of comparison of thinning procedures.

(III) FIRST THINNINGS OF YOUNG NATURAL REGENERATION.

A. *Object of investigations.*

1. To determine the age (or size) at which the first thinning should be made.
2. To determine the best method of doing the first thinning.
3. Incidentally, to determine the extent of any ill effects which may result from departing from the age and method silviculturally best suited to the species and conditions.

B. *Factors involved.*

(1) *Density of regeneration.*—Obviously in a general way, the more open the crop, the later the necessity for thinning comes in.

(2) *Natural differentiation of stems in a crowded crop.*—This is known to vary considerably with species and conditions. Sometimes the individuals which will form the crop of the future soon take the lead and appear to suffer but little from the competition of the smaller stems standing between them. More often but little differentiation takes place, and all the stems tend to grow up together with narrow constricted crowns.

(3) *Regularity of spacing of stems.*—It has to be determined whether these early thinnings should lay more stress on uniformity of spacing—at least for the stems of the future—than on individual stem quality.

(4) *Intensity.*—In very young crops, crown thinning can hardly be differentiated from ordinary, and it is usually desirable to thin as heavily as can be permitted, to enhance increment and to avoid the necessity of making repeated unremunerative thinnings.

(5) *Quality of locality.*—Regeneration is slower to close up either naturally or after thinnings on the poorer sites, and optimum treatments varies accordingly. Growth in early years is liable to be determined more by local and often temporary influences, than by actual quality of locality, so that the latter should be considered as reflected by the older growth in the vicinity as well as by the regeneration under investigation.

(C) *Method of investigation.*

The standard sample plot procedure as given in Chapter X and in this Chapter on p. 222 meets all requirements. Only small trees are in question so that cross marking and numbering are not usually necessary and quite small plots (say 0·2 acre) will give the information required. Although it is very useful to be able to continue these thinning plots for the later stages of growth, it is desirable to keep the immediate object more closely in view, and often to utilise patches of regeneration which would be unsuitable on account of small size, situation, or other reasons, for maintenance as Permanent Sample plots. More than usual care will be required that the selected plots are initially comparable, and possess comparable conditions for growth as regards soil, exposure, proximity of other growth, and extraneous agencies such as grazing, and as this is a difficult matter, several sets of plots should be considered essential. Practical considerations will usually limit the number of plots in a set to 2-4, so that grades of thinning should be investigated in one set, thinning being done at the same age for all, while year of thinning should be varied in a different set, all plots of the set being thinned to the same grade.

A period of years during which the investigation is to be continued, at least in the first place, should be decided, and the mode of comparing results in the several plots should be foreseen as far as possible because the data to be recorded will depend on it. Crop height, number of stems, average diameter and quality of stems and crowns will be of primary importance in deciding the further development of the crop, and statistics for these characters must be collected. It can only be left till the end of the investigation to decide to what extent high values for some of these factors are offset by deficiencies in others.

The series of plots required for such an investigation should be determined as follows. Firstly only one forest type or quality can be dealt with at a time. Thinning on C and D grades will

usually require to be tested with either an unthinned or B grade plot as control (choice depending on local conditions), and a research "E" grade added if possible. In some cases, it may be desired to test thinning on the more mechanical basis of minimum spacing subject to such provisos as the type of crop calls for, and the set will consist of plots thinned to different minimum spacings, perhaps with different provisos. In an age (or size) set, the set may consist of plots in which thinnings on say C grade, or a minimum spacing of 6′, are made when the dominant stems average 4″, 6″ and 8″ in diameter, *or* 4″ in diameter and 10 and 20 years later, *or* 20′, 40′, and 50′ in height. In such sets it is obviously of the utmost importance to select, demarcate and record the whole set of plots at the start so that initial comparability can be guaranteed.

D. Field work.

Standard sample plot (Chapter X) and thinning (Chapter XI, p. 225) procedure is followed as qualified for crops of small trees not necessarily to be maintained for a long period.

E. Computations.

Total production is of less value in the present connection than average dimensions. Of the five different bases for comparison listed on p. 227, (ii) and (v), averages for all the dominant trees and for the largest x per acre, are most useful.

(IV) FIRST THINNINGS OF YOUNG PLANTATIONS.

A. Objects.

As in the foregoing section, p. 230.

B. Factors involved.

These are as in the foregoing sub-chapter, but the following special considerations also come into question under the heads listed there :—

(1) *Density.*—Initial spacing, with percentage of unreplaced casualties and their distribution, determine the density of plantations. The stems being usually regularly spaced, can make fuller use of soil and light than natural regeneration. Spacing in plantations is thus included in the scope of the present head.

(2) *Stem differentiation.*—All conditions being more uniform than in natural regeneration, stem differentiation tends to be slower, and intense competition more prolonged if thinnings are not done.

(3) *Spacing after thinning.*—"Mechanical" thinning (subject of course to a few obvious and necessary provisos), stressing even distribution over slight superiority in form or vigour, may require study.

(4) *Intensity.*—With the usually slight differentiation existing in young plantations, the standard thinning grades are sometimes difficult to apply. Number of stems per acre at the selected age on a given quality of locality thus becomes the natural basis, with diameter replacing age when quality is not known.

(5) *Quality of locality.*—The poorer the quality, the more stems per acre at a given age. For a given diameter the number of stems also tends to be more on the poorer quality, but as a rule there is but little difference. Hence the remark in the last paragraph.

C. Methods of Investigation.

The standard sample plot procedure as given in Chapter X and this Chapter, p. 222, is applicable with the simplifications given for crops of small trees.

The age at which the first thinning may be done, and the proportions of stems to be removed are selected to cover the range considered necessary from such data and observations as are available. It is inadvisable to begin with too many plots, although plantations offer exceptional facilities for laying out sets of plots, and the range should be so taken that the risk of its being inadequate is small.

The method of conducting the investigations and comparing results given on p. 231 for natural regeneration, is applicable here also. In addition, the possibility of varying initial spacing should be included, and plantations specially raised with spacing ranging well on both sides of what is estimated as likely to prove the optimum. Line spacings as well as the more usual square or triangular spacing may call for trial.

D. Field work.

The standard sample plot procedure is simplified in one or two respects.

(1) As noted, plots may be smaller if necessary, though in view of the desirability of maintaining them for a further indefinite period after the immediate purpose is fulfilled, they should not be unnecessarily so.

(2) The Plot Chart can be prepared mechanically owing to the uniform spacing of the plants. The boundaries should however be surveyed in the usual way as the spacing will rarely be sufficiently accurate to be accepted without check.

(3) The details of the method of thinning will be decided beforehand as part of the treatment under investigation. As noted, it may be primarily mechanical, such as the removal of every alternate plant, and the standard scale will usually require amplification (as by reference to the number of stems per acre) to be applicable to these plantations.

(4) Costs and value of material removed being usually of considerable importance in the present connection, they should be recorded whenever possible, with notes as to the relationship they might bear to the estimated values for large scale operations.

(5) Sample trees are usually obtainable with a minimum of difficulty, and can usually be measured standing if required.

E. Computations.

As for natural regeneration, *see* p. 232 and p. 227.

(V) Thinning in mixed crops.

A. Objects.

Attention will be specially directed to obtaining the maximum increment possible on the most valuable species, at the same time allowing the subsidiary species to fill the role allotted to them, whether of soil protection or production of a special class of material.

B. Factors involved.

In addition to those involved in all thinning investigations, the following further complications come into question:—

(1) Relative rates of growth of the species concerned.
(2) The variations of those rates with age.
(3) Relative light requirements.
(4) Varying proportions in the mixture.
(5) Special distribution in the mixture—stem-wise or in groups.

C. Methods of investigation.

The problem is so complicated that there is little hope of definite results unless the number of variables is reduced to the least possible. Thus the mixtures to be studied first should be simple ones of two species only, or (definitely less satisfactory) only one important species to be favoured above all the rest. Age should be reasonably uniform and so plantations offer the best opportunities for this study,—as also because they provide plots with the same proportion of the species concerned with the same type of intermingling. Results from plots in which these factors vary appreciably can never give conclusive and convincing results as interpretation must largely depend on the relative significance given to the several variables—a matter of opinion for the most part.

In few other investigations is it so important as in these to have a clearly defined object in view and a clear statement of the treatment to be applied.

D. Field work.

As noted above, plantations offer the best facilities for adding to our knowledge on this subject. As it is the early thinnings which have the greatest effect on development, it is often possible to raise mixed plantations with the stem distribution and age difference (if any) considered most promising for the end in view, whilst many young plantations exist in which mixtures have been raised, e.g., teak and *Xylia*, *Dalbergia* and *Eugenia*, etc.

Young regeneration, notably the mixed conifer regeneration of the Himalayas, also offer opportunities for investigations which are much called for, as lack of continuity of treatment has often shifted the balance between the species beyond recovery (as for example for *Pinus excelsa* among *Cedrus Deodara*). It is to such cases that the italicised remark in the foregoing section applies.

Sample trees are required for each species.

Plots will require maintenance for 10-20 years in the first place.

E. Computations.

Volumes and average dimensions should be calculated as described in the previous sub-chapter (IV). Interprotation of results is again even more difficult with the extra factors to be taken into consideration, but if the object of the investigation has been well drafted, an answer should be obtained.

CHAPTER XII.

Compilation of Yield Tables.

(I) General considerations.

Yield tables should present in summarised form all the essential data for the development of fully stocked and regularly thinned even-aged crops, from their origin to at least an age when current and mean annual increment have passed their culmination. The primary requirement is knowledge of volume production for main crop and total yield, intermediate yields being given by the difference of these two quantities but crop averages are also required for diameter, height, and number of stems, and it is customary to add crop basal area and form factors though these quantities are derivable from the others. Stand tables shewing the average composition by diameter classes of crops of given crop diameter form an important supplement, essential for conversion of volume yield tables to money yield tables.

Separate tables are required for each method of treatment (notably differences in thinning) and in almost all cases development varies according to the quality of locality between such wide limits that separate tables are necessary for each of a series of arbitrarily delimited quality classes or of natural forest types.

A yield table gives all the data for a determination of the growing stock and increment of the normal forest, volume figures being capable of direct summation as equal distribution of the age classes is an essential to normality.

Ex. 39. *Normal forest of* sal, *average Quality II, on 100 year rotation. From Howard's yield tables, considering stem timber only, final yield volumes per acre are*—

Age	10	20	30	40	50	60	70	80	90	100	Total.
Volume per acre	0	0	0	1,040	2,060	2,790	3,380	3,785	4,060	4,265	21,380

This volume of 21,380 c.ft. timber stands on 10 acres ready for thinning, the volume which may be removed as thinnings being 1,295 direct from the tables. On the coupes 99—91 years old, there will be the final yield for age 100 (before thinning) minus *1—9 annual increments or 45 annual increments in all, and similarly for 89—81, etc. So the sum of the current annual increments* (*556*) *multiplied by 45*, i.e., *25,020 c.ft. is subtracted from 213,800, giving 188,780 c.ft. as the normal growing stock on 100 acres before thinning, or 183,220 immediately after felling the final yield of 4,265 c.ft. and the thinnings amounting to 1,295 c.ft.* (See also Schlich's Manual of Forestry, Vol. III, 1925, p. 214).

Ex. 40. *Normal Annual Increment for the same forest, per 100 acres.*

Period	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100
Increment per acre	0	0	0	104	102	87	82	69·5	59	52·5

Total on 10 acres 556 c.ft.

Total on 100 acres 5,560 c.ft.

This figure is of course equal to the Total Yield at 100 years of the yield table, since each year one acre of mature crop could be felled (*4,265 c.ft.*) *and a full set of thinnings made* (*1,295 c.ft.*).

The procedure laid down for the computation of sample plots aims at collecting the data for each in the form most convenient for compilation of yield tables, and almost every figure required can be obtained direct from the Form 6 of the plot.

The yield tables for Indian species which have been published so far, are listed in the following table :—

Species.	Locality, etc.	Number of quality classes.	Date.	Reference.
Tectona grandis . .	Nilambur	5	1916	Working Plan.
Shorea robusta . .	United Provinces, High Forest.	3	1923	Ind. For. Rec., Vol. X, Part III.
Shorea robusta . .	Coppice	2	1926	Ind. For. Rec., Vol. XII, Part IV.
Dalbergia Sissoo . .	Natural crops . .	1	1925	For. Bull. 62.
Pinus longifolia . .	N. W. India . .	3	1926	Ind. For. Rec., Vol. XII, Part V.
Cedrus Deodara . .	Ditto . .	3	1926	Ind. For. Rec., Vol. XII, Part VI.
Pinus excelsa . .	Ditto . .	3	1929	Ind. For. Rec., Vol. XIII, Part X.

Of these, that for teak was made in the Nilambur division expressly for the plantations there, using local units of measurement and a rather different field and computation technique from that used for all the remainder. The latter have all been compiled on similar lines based on sample plots laid out, measured and computed as prescribed in the 1921 Statistical Code, except that the last mentioned, for *Pinus excelsa*, incorporates a few additional features foreshadowing the prescriptions and recommendations of this 1930 Code. Compilation has been done at the Forest Research Institute on all available data from all provinces.

It is not desirable to lay down any stereotyped method for compiling the sample plot data into yield tables. The following sections aim at shewing how the existing tables have been obtained and suggesting the chief alternatives at each step.

(II) Differentiation of site classes (quality classes).

(*a*) Site classes are best based on the crop age and average height of the biggest trees. This average height may be read off the Height/Age curve as the height corresponding to the mean diameter (calculated from basal area) of the 100 biggest diameters per acre for each plot (i.e., of the first two groups in most cases). Crop age is directly available from Sample Plot Form 6, or may be taken from the Diameter Age curve for the same mean diameter, the difference being small.

This crop age has been read from the Age/Diameter curve at the mean diameter for the *whole* crop, and not as that for the 100 biggest diameters.

All hitherto published yield tables give mean data for quality classes delimited on the basis of the average height of all trees. The relationship between height of biggest trees and average height is being computed and will be published. It is suggested the former be termed '*Top height*.'

Quality classes should be numbered with Roman ordinals, I, II, III......, the highest quality being I.

(*b*) The crop or top height of all plots should be plotted against age on a suitable scale.

(*c*) The further stages vary according to the method followed in delimiting qualities. Two methods are described in the following sections, and a third exists based on Cajander's theory of forest types. The last mentioned has been adopted by Ilvessalo for Finland (*24*), and does not require further elaboration here.

Method I, based on Baur's principle of sub-division of limiting curves.

(*d*) The plotted distribution should be carefully examined for the selection of guiding points (say 1 per 20 years) along the top and bottom limits, tentatively rejecting the obviously abnormal points.

(*e*) Limiting curves should be drawn through the guiding points making use of any curves available from height analysis in the plots concerned. The upper part of each such curve from analysis should be given more weight than its lower parts.

(*f*) The number of qualities to be differentiated should be fixed with reference to—

(1) Difference between the leading curves.
(2) Practical limits of accuracy in height determination.
(3) Closeness of management foreseen.

(*g*) The space between the limiting curves should then be divided symmetrically by a number of curves one less than the number of qualities to be differentiated.

(*h*) Three quality classes will usually meet requirements and so have most usually been differentiated.

The numbers in published Indian Yield tables are noted in the list given above on p. 236, but it may be noted that *Shorea* requires one quality below the lowest given, and *Tectona* needs one above and one below. The majority of European tables distinguish five qualities.

Method II, based on equal steps in height or volume values at a given age.

This method described below is commonly followed in America (*site classes*), the value taken being height. It has also been applied in the recently published yield tables for *Pinus excelsa*, using crop height at 90 years. See Curve IX, Ind. For. Rec., Vol. XIII, Pt. X. Tables have been published in Europe using total yield at 100 years but application is more difficult.

A larger number of classes is usually distinguished as compared with Method I.

(d_1) A single mean curve is drawn over the points with the help of any stem analysis curves available. The points may be grouped and averaged first if found desirable.

(e_1) At any convenient age after the period of rapid height growth is completed, preferably somewhat less than the most usual rotation age for the species, a convenient number of equal height intervals (usually 20′, 25′ or 30′ (are selected to limit site classes.

(f_1) A set of curves through the points so obtained is drawn symmetrically with the guiding curve drawn under d_1.

(III) Main crop curves and tables by quality or site-age classes.

A. Preliminary computations.

1. Plot data (Sample Plot Form 6) are sorted by quality or site classes by crop height or top height as preferred.

2. For each quality, the following averages for the main crop only may be obtained for each decade.

(i) Basal area per acre.
(ii) Average height (for whole crop, not top height).
(iii) Total number of trees per acre.
(iv) Timber volume per acre.
(v) Stem smallwood volume per acre.
(vi) Percentage of branch smallwood to stem smallwood.
(vii) Average diameter.
(viii) Form factors for timber and for stem smallwood.

A plot which appears to belong to different quality classes at successive measurement —such plots are of quite usual occurrence— should be allotted to one or other quality class after due consideration of all relevant factors. As a rule, the indications of the later measurements will be more reliable.

Average diameter should be obtained for each decade by dividing the sum of the basal areas per acre by the number of stems, and finding the diameter corresponding to this average stem basal area—not by averaging the plot diameters directly. Comparable procedure for height is not necessary as the difference involved is negligible, but form factors should similarly be obtained by totalling the volumes and dividing by average height and average basal area per acre.

B. Curves.

1. Sets of limiting curves by qualities or site classes may then be drawn over the plotted decade averages for each of these quantities, smoothed, and harmonised.

2. Individual plot values may again be plotted on the harmonised curves to permit of the consideration of deviations with a view to rejection. Rejections should be based mainly on deviations from the basal area curve.

For this purpose, it is advisable to compute the standard deviation of the individual points for each curve; the criterion for rejection is that for any point, the actual deviation from the curve may not appreciably exceed three times the calculated standard deviation.

It should be remembered that under existing conditions, our older plots often carry per acre a much larger volume, basal area and number of trees than will future crops which have been regularly thinned from early life. In crops of the latter type a large part of the increment is removed in the form of thinnings, and after a certain age, thinnings equal and may even *exceed* the periodic increment, so that basal area remains constant except for very insignificant deviations. Therefore plots indicating higher values in these respects should be suspected of being abnormal and should be examined for rejection. The mean should thus tend towards the lower half of the zone of points for each site class.

3. Average curves should be drawn symmetrically between the limiting curves for the several qualities obtained by Step 2.

C. Tabulation and adjustment of curves.

1. Values for 10, 20, 30......years can be read from the curves and tabulated by qualities.

2. Branch smallwood volume should be calculated from its percentage relationship to stem smallwood for each decade.

3. The average diameter (D), number of trees per acre (N), and the basal area per acre (S) curves should be mutually readjusted so that for each decade, number of trees per acre *times* average basal area per tree (a) *equal* basal area per acre, i.e., so that $Na=S$. This adjustment should be made mainly on the number of stems curve.

4. The values of crop form factor (F), average height (H), and basal area per acre (S), can be read from the curves. Volumes per acre should be calculated for each decade, and a second set of volume curves drawn, (i.e., for $F \times H \times S$). These $F \times H \times S$ curves should be checked against the original volume curves drawn under B. 3. above. Any discrepancy found should be eliminated by adjustment of the two curves as far as possible, and in case of doubt, the $F \times H \times S$ value should be given more weight.

(IV) Subsidiary crop.

(*a*) For each site class, the following averages can be computed for each decade and curved over age :—

Main and subsidiary crop together.

1. Total yield in stem imber per acre.
2. Total yield in basal area per acre.
3. Total yield in stem smallwood per acre.
4. Current periodic increment (10 year periods).

Subsidiary crop only.

1. Average diameter.
2. Average height.
3. Percentage of branch smallwood to stem smallwood.

In the case of crown thinnings, the average height of the subsidiary crop will as a rule be greater than the corresponding main crop values, and the average diameters may shew the same feature.

(*b*) The basal area and volume for the subsidiary crop can then be calculated as differences between values read off the curves drawn above, and the corresponding values for the main crop already determined.

(*c*) From the current periodic increment read off the curves (middle of decades), thinnings can also be calculated from the following relationship :—

$T=I-(V_2 \quad V_1)$, where

T=Volume of thinning.

I=Periodic increment (10 years).

V_1=Main crop volume at the beginning of the period.

V_2=Main crop volume at the end of the period.

These values may then be compared with those directly determined under (*b*) above, and any differences eliminated by readjustment of curves if possible.

If subsidiary crop timber and smallwood are very irregular values, as will be the case when the majority of the plots have had only one or few measurements, the procedure prescribed may be found unsatisfactory. If this is so, percentage of subsidiary crop timber and smallwood to the corresponding main crop values may be calculated, averaged and smoothed by curving to derive tentative values.

(*d*) The number of trees in the subsidiary crop is given by the successive reductions in the numbers standing as main crop in each decade already determined. Basal area being known, mean tree basal area and diameter are readily deduced.

(*e*) Branch smallwood can be obtained by applying curved percentages to corresponding stem smallwood volumes.

(V) Alternative methods for curve construction.

The possibility of applying the principles of anamorphosis or alinement charts to yield table curves should be considered (25).

The advantages of *anamorphosis* are that the curves are all straight lines and so simple to construct, and there is fuller scope for the application of statistical technique.

The main objection is that application of this method results in mean and current annual increment for all site classes culminating at the same age, which is contrary to accepted notions.

Alinement charts have the following advantages :—

(1) The number of curves to be fitted is reduced with consequent saving in labour, and the curves are usually straight lines.

(2) Interpolation is simple.

(3) Final results are presented in the form of compact diagrams which are as easy to read as the tables and in some ways more convenient.

(VI) Statement of deviations from basic curves.

(*a*) For each quality class or the whole data, average error and aggregate error may be calculated for the following values, and curved over crop d.b.h.—

1. Number of stems per acre.
2. Basal area per acre.
3. Average diameter.
4. Volume per acre.

Aggregate error is computed as the difference between the sum of estimated values of all the plots interpolated for age and quality and the sum of the actual values of the plots. The average and aggregate errors indicate the degree of closeness of fit of the curves to the data, and so the weakness of any of the tabular values is rendered apparent.

(VII) Application of yield tables.

(*a*) Yield tables give only smoothed mean values, and even when all the conditions for their application are fulfilled, individual variations from the mean are always to be expected in application to specific instances.

(*b*) Yield tables can only be applied to crops which can be considered as even-aged

(*c*) For calculation of growing stock, the average quality, age and density of the crop must be estimated for each unit of area and the corresponding figure derived from the table.

(*d*) *Quality* may be determined by estimating the average height of the 50 biggest dominant and co-dominant trees per acre, i.e., of the biggest trees spaced about 30′ apart, and interpolating for this height and the known age in the yield

table curves or tables. The precise procedure will depend on the way the yield tables in question have been prepared.

(e) *Age* should be determined by averaging ring countings of a few dominant trees (with the addition of the standardised or estimated allowance for age to stump height) except when it is known from records.

- The possible discrepancy involved in determining height from some trees and age from others is not in practice serious.

(f) *Density* should be estimated from the closeness of the canopy, full density being taken as the maximum known to occur in crops which have been suitably tended, for the given species at the age concerned.

It is possible for the density to exceed unity in crowded crops whose tending has been neglected.

(g) Stands which at any time are found to be normal according to the yield tables for the given site and age, will not remain so unless thinned on the lines forming the basis of the yield tables used.

(h) The increment of understocked stands is not necessarily less than that of fully-stocked stands, owing to a possibly higher rate of growth in basal area and improvement in form.

(j) Over-stocked stands contain a greater volume than is shown in the yield tables, and if this excess is not removed, there may be a resultant stagnation in diameter increment and mortality may increase.

(VIII) Stand tables.

(a) For each plot, the number of diameters per acre should be calculated by 1″ diameter classes, giving the 'stem distribution series'.

(b) For each 1″ diameter class (crop diameter), the stem distribution series of plots concerned should be totalled and averaged.

Generally all quality classes may be taken together, but this should not be done if the data indicate that differentiation by quality classes exists as Cajander found with his types.

(c) The figures of each of the average stem distribution series should be totalled cumulatively, and these totals expressed as percentages of the total number of stems. The totalling begins from the smallest diameters and the totals represent numbers up to limiting diameters.

(d) These percentage series for each site-age class should be examined with a view to determining whether they represent reasonably normal frequency distribution, as they should for even-aged crops. This should be done by plotting the percentages against diameters on frequency paper (which is so ruled that normal frequencies, expressed cumulatively, fall on a straight line). If frequency paper is not available, a mathematical or graphic test should be applied using the original percentages (not cumulative).

(e) If the distribution can be taken as normal, a set of smoothed curves for the cumulative percentages may be drawn and harmonised, and average values read from the curves at each whole inch.

Usually the data will not be numerous enough to even out errors of sampling, with the result that it will be extremely difficult to draw an acceptable set of curves; to overcome this difficulty, a more technical procedure is called for.

In the case of skew distribution, the possibility of using the alinement chart method should be considered.

The stand table for any given crop diameters such as those given in the yield table for successive decades, can be derived directly by interpolation between the curves.

(*f*) If it is found that the distribution can be taken as normal, the diameters corresponding to 50 and 84 per cent. (cumulative) should be read off. The 50 per cent. figure represents average diameter (arithmetic mean), and the difference between the 84 per cent. and 50 per cent. figures represents its standard deviation.

In the case of definitely skew distribution, laborious mathematical treatment is called for.

(*g*) The average diameters and standard deviations should then be smoothed by curving over the actual crop diameters taken from the basic data tables derived from basal area, and finally read off against each whole inch.

(*h*) The stand tables shewing the percentage of trees exceeding given diameter limits for any crop diameter, should be derived graphically by plotting average diameter [as in (*c*)] and standard deviation on frequency paper, or by calculation with the help of suitable tables.

Stand tables may also be prepared for any given crop showing :—

(*a*) Distribution of stems by d.b.h. classes of any desired interval.

(*b*) Distribution of basal area or volume of stems for the same d.b.h. classes.

Ex. 41. *An example of Stand Tables will be found on pp. 20-23 of Ind. For. Rec., Vol. XIII, Pt. X, Yield Tables for Blue Pine.*

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APPENDIX VI.

$$F_1 = \frac{\cdot 8453}{\sqrt{n(n-1)}} \times 1\cdot 4826 \qquad F_2 = \frac{\cdot 8453}{n\sqrt{n-1}} \times 1\cdot 4826$$

No.	F_1	F_2	No.	F_1	F_2	No.	F_1	F_2	No.	F_1	F_2	No.	F_1	F_2	No.	F_1	F_2
1	..	..	37	·0344	·0056	73	·0173	·00202	109	·0116	·00111	145	·0086	·00072	181	·0070	·00052
2	0·8863	·6267	38	·0334	·0055	74	·0170	·00199	110	·0114	·00109	146	·0086	·00071	182	·0070	·00051
3	·5116	·2955	39	·0326	·0052	75	·0168	·00194	111	·0113	·00108	147	·0086	·00071	183	·0068	·00051
4	·3618	·1809	40	·0317	·0050	76	·0166	·00190	112	·0113	·00106	148	·0085	·00070	184	·0068	·00050
5	·2802	·1253	41	·0310	·0049	77	·0164	·00187	113	·0111	·00105	149	·0085	·00069	185	·0068	·00050
6	·2288	·0931	42	·0302	·0046	78	·0162	·00184	114	·0110	·00103	150	·0085	·00068	186	·0068	·00050
7	·1933	·0731	43	·0295	·0044	79	·0160	·00179	115	·0110	·00102	151	·0083	·00068	187	·0067	·00049
8	·1675	·0592	44	·0288	·0043	80	·0157	·00176	116	·0108	·00101	152	·0083	·00067	188	·0067	·00049
9	·1477	·0492	45	·0282	·0042	81	·0156	·00173	117	·0108	·00099	153	·0082	·00066	189	·0067	·00048
10	·1321	·0418	46	·0276	·00406	82	·0154	·00170	118	·0107	·00098	154	·0082	·00066	190	·0067	·00048
11	·1195	·0360	47	·0270	·00393	83	·0151	·00166	119	·0105	·00097	155	·0082	·00065	191	·0065	·00648
12	·1091	·0314	48	·0264	·00381	84	·0150	·00163	120	·0105	·00096	156	·0080	·00065	192	·0065	·00047
13	·1004	·0279	49	·0258	·00369	85	·0148	·00162	121	·0104	·00095	157	·0080	·00064	193	·0065	·00047
14	·0930	·0248	50	·0254	·00357	86	·0147	·00159	122	·0104	·00093	158	·0080	·00063	194	·0065	·00047
15	·0864	·0224	51	·0248	·00347	87	·0145	·00156	123	·0102	·00092	159	·0079	·00063	195	·0064	·00046
16	·0809	·0202	52	·0243	·00338	88	·0144	·00153	124	·0101	·00091	160	·0079	·00062	196	·0064	·00046
17	·0761	·0184	53	·0239	·00328	89	·0142	·00150	125	·0101	·00090	161	·0079	·00062	197	·0064	·00045
18	·0716	·0169	54	·0234	·00319	90	·0141	·00148	126	·0099	·00089	162	·0077	·00061	198	·0064	·00045
19	·0678	·0156	55	·0230	·00310	91	·0138	·00145	127	·0099	·00088	163	·0077	·00060	199	·0064	·00045
20	·0643	·0144	56	·0225	·00302	92	·0136	·00142	128	·0098	·00087	164	·0077	·00060	200	·0062	·00044
21	·0611	·0133	57	·0222	·00294	93	·0135	·00141	129	·0098	·00086	165	·0076	·00059			
22	·0583	·0125	58	·0218	·00286	94	·0133	·00138	130	·0096	·00085	166	·0076	·00059			
23	·0557	·0116	59	·0215	·00279	95	·0132	·00136	131	·0096	·00084	167	·0076	·00058			
24	·0534	·0108	60	·0211	·00271	96	·0132	·00133	132	·0095	·00083	168	·0074	·00058			
25	·0511	·0102	61	·0208	·00265	97	·0130	·00132	133	·0095	·00082	169	·0074	·00057			
26	·0491	·0096	62	·0203	·00259	98	·0129	·00130	134	·0093	·00081	170	·0074	·00057			
27	·0473	·0090	63	·0200	·00252	99	·0128	·00128	135	·0093	·00080	171	·0074	·00056			
28	·0455	·0086	64	·0197	·00246	100	·0126	·00126	136	·0092	·00079	172	·0073	·00056			
29	·0440	·0082	65	·0196	·00240	101	·0125	·00124	137	·0092	·00078	173	·0073	·00055			
30	·0426	·0077	66	·0191	·00236	102	·0123	·00122	138	·0090	·00078	174	·0073	·00055			
31	·0411	·0074	67	·0188	·00230	103	·0122	·00120	139	·0090	·00077	175	·0071	·00054			
32	·0397	·0070	68	·0185	·00225	104	·0122	·00119	140	·0090	·00076	176	·0071	·00054			
33	·0385	·0067	69	·0182	·00221	105	·0120	·00117	141	·0089	·00075	177	·0071	·00053			
34	·0374	·0064	70	·0181	·00215	106	·0119	·00115	142	·0089	·00074	178	·0071	·00053			
35	·0363	·0061	71	·0178	·00211	107	·0117	·00114	143	·0087	·00074	179	·0070	·00052			
36	·0353	·0059	72	·0175	·00206	108	·0117	·00112	144	·0087	·00073	180	·0070	·00052			

APPENDIX VII.

Areas of Circles.

Diameters 0·1″ to 60·9″.

Area o circles for diameters of 1 inch to 31 inches.

Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.
0·0	0·0000	4·0	0·0873	8·0	0·3491	12·0	0·7854	16·0	1·3963	20·0	2·1817	24·0	3·1416	28·0	4·2761
·1	·0001	·1	·0917	·1	·3579	·1	·7986	·1	1·4138	·1	2·2036	·1	3·1679	·1	4·3067
·2	·0002	·2	·0963	·2	·3668	·2	·8118	·2	1·4314	·2	2·2256	·2	3·1942	·2	4·3374
·3	·0005	·3	·1009	·3	·3758	·3	·8252	·3	1·4492	·3	2·2477	·3	3·2207	·3	4·3682
·4	·0009	·4	·1056	·4	·3849	·4	·8387	·4	1·4670	·4	2·2699	·4	3·2471	·4	4·3001
·5	·0014	·5	·1105	·5	·3941	·5	·8523	·5	1·4849	·5	2·2922	·5	3·2748	·5	4·4301
·6	·0020	·6	·1154	·6	·4034	·6	·8660	·6	1·5030	·6	2·3146	·6	3·3006	·6	4·4612
·7	·0027	·7	·1205	·7	·4129	·7	·8798	·7	1·5212	·7	2·3371	·7	3·3275	·7	4·4925
·8	·0035	·8	·1257	·8	·4224	·8	·8937	·8	1·5394	·8	2·3597	·8	3·3545	·8	4·5238
·9	·0044	·9	·1310	·9	·4321	·9	·9077	·9	1·5578	·9	2·3825	·9	3·3816	·9	4·5553
1·0	0·0055	5·0	0·1364	9·0	0·4418	13·0	0·9218	17·0	1·5763	21·0	2·4053	25·0	3·4088	20·0	4·5869
·1	·0067	·1	·1418	·1	·4517	·1	0·9360	·1	1·5949	·1	2·4283	·1	3·4261	·1	4·6186
·2	·0079	·2	·1474	·2	·4617	·2	0·9504	·2	1·6136	·2	2·4514	·2	3·4636	·2	4·6504
·3	·0092	·3	·1532	·3	·4718	·3	0·9648	·3	1·6324	·3	2·4745	·3	3·4911	·3	4·6823
·4	·0107	·4	·1590	·4	·4820	4	0·9794	·4	1·6513	·4	2·4978	·4	3·5188	·4	4·7143
·5	·0123	·5	·1650	·5	·4923	·5	0·9941	·5	1·6703	·5	2·5212	·5	3·5465	·5	4·7464
·6	·0140	·6	·1710	·6	·5027	·6	1·0089	·6	1·6894	·6	2·5447	·6	3·5744	·6	4·7787
·7	·0158	·7	·1772	·7	·5132	·7	1·0237	·7	1·7087	·7	2·5684	·7	3·6024	·7	4·8110
·8	·0177	·8	·1835	·8	·5238	·8	1·0387	·8	1·7280	·8	2·5921	·8	3·6305	·8	4·8435
·9	·0197	·9	·1899	·9	·5345	·9	1·0538	·9	1·7475	·9	2·6159	·9	3·6587	·9	4·8760
2·0	0·0218	6·0	0·1963	10·0	0·5454	14·0	1·0690	18·0	1·7671	22·0	2·6398	26·0	3·6870	30·0	4·9087
·1	·0240	·1	·2029	·1	·5561	·1	1·0843	·1	1·7868	·1	2·6638	·1	3·7154	·1	4·9415
·2	·0264	·2	·2096	·2	·5675	·2	1·0997	·2	1·8066	·2	2·6880	·2	3·7439	·2	4·9744
·3	·0289	·3	·2164	·3	·5787	·3	1·1153	·3	1·8265	·3	2·7122	·3	3·7725	·3	5·0074
·4	·0314	·4	·2234	·4	·5900	·4	1·1309	·4	1·8465	·4	2·7366	·4	3·8013	·4	5·0405
·5	·0341	·5	·2304	·5	·6014	·5	1·1467	·5	1·8666	·5	2·7611	·5	3·8301	·5	5·0737
·6	·0369	·6	·2376	·6	·6129	·6	1·1626	·6	1·8869	·6	2·7857	·6	3·8591	·6	5·1071
·7	·0398	·7	·2448	·7	·6245	·7	1·1785	·7	1·9072	·7	2·8104	·7	3·8882	·7	5·1405
·8	·0428	·8	·2522	·8	·6362	·8	1·1946	·8	1·9277	·8	2·8352	·8	3·9174	·8	5·1740
·9	·0459	·9	·2597	·9	·6481	·9	1·2108	·9	1·9482	·9	2·8602	·9	3·9467	·9	5·2077
3·0	0·0491	7·0	0·2673	11·0	0·6600	15·0	1·2272	19·0	1·9689	23·0	2·8852	27·0	3·9761	31·0	5·2414
·1	·0524	·1	·2750	·1	·6721	·1	1·2437	·1	1·9897	·1	2·9103	·1	4·0056	·1	5·2753
·2	·0559	·2	·2828	·2	·6842	·2	1·2602	·2	2·0106	·2	2·9356	·2	4·0353	·2	5·3093
·3	·0594	·3	·2907	·3	·6965	·3	1·2768	·3	2·0316	·3	2·9610	·3	4·0650	·3	5·3434
·4	·0631	·4	·2987	·4	·7089	·4	1·2936	·4	2·0527	·4	2·9864	·4	4·0948	·4	5·3776
·5	·0669	·5	·3068	·5	·7214	·5	1·3104	·5	2·0739	·5	3·0120	·5	4·1248	·5	5·4119
·6	·0707	·6	·3151	·6	·7340	·6	1·3274	·6	2·0952	·6	3·0377	·6	4·1548	·6	5·4463
·7	·0747	·7	·3234	·7	·7467	·7	1·3444	·7	2·1167	·7	3·0635	·7	4·1850	·7	5·4808
.8	·0788	·8	·3319	·8	·7595	·8	1·3616	·8	2·1382	·8	3·0894	·8	4·2152	·8	5·5155
·9	·0830	·9	·3404	·9	·7724	·9	1·3789	·9	2·1599	·9	3·1154	·9	4·2456	·9	5·5502

APPENDIX VII—*contd.*

Areas of Circles—*contd.*

Diameters 0·1″ to 60·9″—contd.

Area of circles for diameters of 32 inches to 60 inches

Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.	Diameter in inches.	Area of circle in Sq. ft.
32·0	5·5851	36·0	7·0686	40·0	8·7266	44·0	10·5592	48·0	12·5664	52·0	14·7480	56·0	17·1042	60·0	19·6350
·1	5·6200	·1	7·1079	·1	8·7703	·1	10·6073	·1	12·6188	·1	14·8048	·1	17·1654	·1	19·7005
·2	5·6551	·2	7·1473	·2	8·8141	·2	10·6555	·2	12·6713	·2	14·8617	·2	17·2266	·2	19·7661
·3	5·6903	·3	7·1869	·3	8·8580	·3	10·7037	·3	12·7239	·3	14·9187	·3	17·2880	·3	19·8318
·4	5·7256	·4	7·2265	·4	8·9021	·4	10·7521	·4	12·7767	·4	14·9758	·4	17·3494	·4	19·8976
·5	5·7610	·5	7·2663	·5	8·9462	·5	10·8006	·5	12·8295	·5	15·0330	·5	17·4110	·5	19·9636
·6	5·7965	·6	7·3062	·6	8·9904	·6	10·8492	·6	12·8825	·6	15·0903	·6	17·4727	·6	20·0296
·7	5·8321	·7	7·3461	·7	9·0348	·7	10·8979	·7	12·9356	·7	15·1478	·7	17·5345	·7	20·0958
·8	5·8678	·8	7·3862	·8	9·0792	·8	10·9467	·8	12·9887	8	15·2053	·8	17·5964	·8	20·1620
·9	5·9036	·9	7·4264	·9	9·1238	·9	10·9956	·9	13·0420	·9	15·2630	·9	17·6584	·9	20·2284
33·0	5·9396	37·0	7·4667	41·0	9·1684	45·0	11·0447	49·0	13·0954	53·0	15·3207	57·0	17·7206		
·1	5·9756	·1	7·5072	·1	9·2132	·1	11·0938	·1	13·1489	·1	15·3786	·1	17·7828		
·2	6·0118	·2	7·5477	·2	9·2581	·2	11·1431	·2	13·2025	·2	15·4366	·2	17·8451		
·3	6·0481	·3	7·5883	·3	9·3031	·3	11·1924	·3	13·2563	·3	15·4947	·3	17·9076		
·4	6·0844	·4	7·6291	·4	9·3482	·4	11·2419	·4	13·3101	·4	15·5528	·4	17·9701		
·5	6·1209	·5	7·6699	·5	9·3934	·5	11·2915	·5	13·3640	·5	15·6112	·5	18·0328		
·6	6·1575	·6	7·7109	·6	9·4387	·6	11·3411	·6	13·4181	·6	15·6696	·6	18·0956		
·7	6·1942	·7	7·7519	·7	9·4842	·7	11·3909	·7	13·4723	·7	15·7281	·7	18·1585		
·8	6·2310	·8	7·7931	·8	9·5297	·8	11·4409	·8	13·5265	·8	15·7867	·8	18·2215		
·9	6·2680	·9	7·8344	·9	9·5754	·9	11·4909	·9	13·5809	·9	15·8455	·9	18·2846		
34·0	6·3050	38·0	7·8758	42·0	9·6211	46·0	11·5410	50·0	13·6354	54·0	15·9043	58·0	18·3478		
·1	6·3421	·1	7·9173	·1	9·6670	·1	11·5912	·1	13·6900	·1	15·9633	·1	18·4111		
·2	6·3794	·2	7·9589	·2	9·7130	·2	11·6416	·2	13·7447	·2	16·0223	·2	18·4745		
·3	6·4168	·3	8·0006	·3	9·7591	·3	11·6920	·3	13·7995	·3	16·0815	·3	18·5381		
·4	6·4542	·4	8·0425	·4	9·8053	·4	11·7426	·4	13·8544	·4	16·1408	·4	18·6017		
·5	6·4918	·5	8·0844	·5	9·8516	·5	11·7932	·5	13·9095	·5	16·2002	·5	18·6655		
·6	6·5295	·6	8·1265	·6	9·8980	·6	11·8440	·6	13·9646	·6	16·2597	·6	18·7293		
·7	6·5673	·7	8·1686	·7	9·9445	·7	11·8949	·7	14·0198	·7	16·3193	·7	18·7933		
·8	6·6052	·8	8·2109	·8	9·9911	·8	11·9459	·8	14·0752	·8	16·3790	·8	18·8574		
·9	6·6432	·9	8·2533	·9	10·0379	·9	11·9970	·9	14·1307	·9	16·4389	·9	18·9216		
35·0	6·6813	39·0	8·2958	43·0	10·0847	47·0	12·0482	51·0	14·1863	55·0	16·4988	59·0	18·9859		
·1	6·7196	·1	8·3384	·1	10·1317	·1	12·0995	·1	14·2419	·1	16·5589	·1	19·0503		
·2	6·7579	·2	8·3811	·2	10·1788	·2	12·1510	·2	14·2977	·2	16·6190	·2	19·1148		
·3	6·7964	·3	8·4239	·3	10·2259	·3	12·2025	·3	14·3536	·3	16·6793	·3	19·1795		
·4	6·8349	·4	8·4668	·4	10·2732	·4	12·2542	·4	14·4097	·4	16·7397	·4	19·2442		
·5	6·8736	·5	8·5098	·5	10·3206	·5	12·3059	·5	14·4658	·5	16·8002	·5	19·3091		
·6	6·9124	·6	8·5530	·6	10·3681	·6	12·3578	·6	14·5220	·6	16·8608	·6	19·3740		
·7	6·9513	·7	8·5962	·7	10·4157	·7	12·4098	·7	14·5784	·7	16·9215	·7	19·4391		
·8	6·9903	·8	8·6396	·8	10·4635	·8	12·4619	·8	14·6348	·8	16·9823	·8	19·5043		
·9	7·0294	·9	8·6831	·9	10·5113	·9	12·5141	·9	14·6914	·9	17·0432	·9	19·5696		

APPENDIX VIII.

Volumes of Cylinders or Sums of Circles.

Diameter in Inches.	Length of cylinder or number of circles.								
	1	2	3	4	5	6	7	8	9
1	0·0055	0·0110	0·0165	0·0220	0·0275	0·0330	0·0385	0·0440	0·0495
2	·0218	·0436	·0654	·0872	·1090	·1308	·1526	·1744	·1962
3	·0491	·0982	·1473	·1964	·2455	·2946	·3437	·3928	·4419
4	·0873	·1746	·2619	·3492	·4365	·5238	·6111	·6984	·7857
5	·1364	·2728	·4092	·5456	·6820	·8184	·9548	1·0912	1·2276
6	0·1963	0·3926	0·5889	0·7852	0·9815	1·1778	1·3741	1·5704	1·7667
7	·2673	·5346	·8019	1·0692	1·3365	1·6038	1·8711	2·1384	2·4057
8	·3491	·6982	1·0473	1·3964	1·7455	2·0946	2·4437	2·7928	3·1419
9	·4418	·8836	1·3254	1·7672	2·2090	2·6508	3·0926	3·5344	3·9762
10	·5454	1·0908	1·6362	2·1816	2·7270	3·2724	3·8178	4·3632	4·9086
11	0·6600	1·3200	1·9800	2·6400	3·3000	3·9600	4·6200	5·2800	5·9400
12	·7854	1·5708	2·3562	3·1416	3·9270	4·7124	5·4978	6·2832	7·0686
13	·9218	1·8436	2·7654	3·6872	4·6090	5·5308	6·4526	7·3744	8·2962
14	1·0690	2·1380	3·2070	4·2760	5·3450	6·4140	7·4830	8·5520	9·6210
15	1·2272	2·4544	3·6816	4·9088	6·1360	7·3632	8·5904	9·8176	11·0448
16	1·3963	2·7926	4·1889	5·5852	6·9815	8·3778	9·7741	11·1704	12·5667
17	1·5763	3·1526	4·7289	6·3052	7·8815	9·4578	11·0341	12·6104	14·1867
18	1·7671	3·5342	5·3013	7·0684	8·8355	10·6026	12·3697	14·1368	15·9039
19	1·9689	3·9378	5·9067	7·8756	9·8445	11·8134	13·7823	15·7512	17·7201
20	2·1817	4·3634	6·5451	8·7268	10·9085	13·0902	15·2719	17·4536	19·6353
21	2·4053	4·8106	7·2159	9·6212	12·0265	14·4318	16·8371	19·2424	21·6477
22	2·6398	5·2796	7·9194	10·5592	13·1990	15·8388	18·4786	21·1184	23·7582
23	2·8852	5·7704	8·6556	11·5408	14·4260	17·3112	20·1964	23·0816	25·9668
24	3·1416	6·2832	9·4248	12·5664	15·7080	18·8496	21·9912	25·1328	28·2744
25	3·4088	6·8176	10·2264	13·6352	17·0440	20·4528	23·8616	27·2704	30·6792
26	3·6870	7·3740	11·0610	14·7480	18·4350	22·1220	25·8090	29·4960	33·1830
27	3·9761	7·9522	11·9283	15·9044	19·8805	23·8566	27·8327	31·8088	35·7849
28	4·2761	8·5522	12·8283	17·1044	21·3805	25·6566	29·9327	34·2088	38·4849
29	4·5869	9·1738	13·7607	18·3476	22·9345	27·5214	32·1083	36·6952	41·2821
30	4·9087	9·8174	14·7261	19·6348	24·5435	29·4522	34·3609	39·2696	44·1783

APPENDIX VIII—*contd.*

VOLUMES OF CYLINDERS OR SUMS OF CIRCLES—*contd.*

Diameter in Inches.	Length of cylinder or number of circles.								
	1	2	3	4	5	6	7	8	9
31	5·2414	10·4828	15·7242	20·9656	26·2070	31·4484	36·6898	41·9312	47·1726
32	5·5851	11·1702	16·7553	22·3404	27·9255	33·5106	39·0957	44·6808	50·2659
33	5·9396	11·8792	17·8188	23·7584	29·6980	35·6376	41·5772	47·5168	53·4564
34	6·3050	12·6100	18·9150	25·2200	31·5250	37·8300	44·1350	50·4400	56·7450
35	6·6813	13·3626	20·0439	26·7252	33·4065	40·0878	46·7691	53·4504	60·1317
36	7·0686	14·1372	21·2058	28·2744	35·3430	42·4116	49·4802	56·5488	63·6174
37	7·4667	14·9334	22·4001	29·8668	37·3335	44·8002	52·2669	59·7336	67·2003
38	7·8758	15·7516	23·6274	31·5032	39·3790	47·2548	55·1306	63·0064	70·8822
39	8·2958	16·5916	24·8874	33·1832	41·4790	49·7748	58·0706	66·3664	74·6622
40	8·7266	17·4532	26·1798	34·9064	43·6330	52·3596	61·0862	69·8128	78·5394
41	9·1684	18·3368	27·5052	36·6736	45·8420	55·0104	64·1788	73·3472	82·5156
42	9·6211	19·2422	28·8633	38·4844	48·1055	57·7266	67·3477	76·9688	86·5899
43	10·0847	20·1694	30·2541	40·3388	50·4235	60·5082	70·5929	80·6776	90·7623
44	10·5592	21·1184	31·6776	42·2368	52·7960	63·3552	73·9144	84·4736	95·0328
45	11·0447	22·0894	33·1341	44·1788	55·2235	66·2682	77·3129	88·3576	99·4023
46	11·5410	23·0820	34·6230	46·1640	57·7050	69·2460	80·7870	92·3280	103·8690
47	12·0482	24·0964	36·1446	48·1928	60·2410	72·2892	84·3374	96·3856	108·4338
48	12·5664	25·1328	37·6992	50·2656	62·8320	75·3984	87·9648	100·5312	113·0976
49	13·0954	26·1908	39·2862	52·3816	65·1770	78·5724	91·6678	104·7632	117·8586
50	13·6354	27·2708	40·9062	54·5416	68·1770	81·8124	95·4478	109·0832	122·7186
51	14·1863	28·3726	42·5589	56·7452	70·9315	85·1178	99·3041	113·4904	127·6767
52	14·7480	29·4960	44·2440	58·9920	73·7400	88·4880	103·2360	117·9840	132·7320
53	15·3207	30·6414	45·9621	61·2828	76·6035	91·9242	107·2449	122·5656	137·8863
54	15·9043	31·8086	47·7129	63·6172	79·5215	95·4258	111·3301	127·2344	143·1387
55	16·4988	32·9976	49·4964	65·9952	82·4940	98·9928	115·4916	131·9904	148·4892
56	17·1042	34·2084	51·3126	68·4168	85·5210	102·6252	119·7294	136·8336	153·9378
57	17·7206	35·4412	53·1618	70·8824	88·6030	106·3236	124·0442	141·7648	159·4854
58	18·3478	36·6956	55·0434	73·3912	91·7390	110·0868	128·4346	146·7824	165·1302
59	18·9859	37·9718	56·9577	75·9436	94·9295	113·9154	132·9013	151·8872	170·8731
60	19·6350	39·2700	58·9050	78·5400	98·1750	117·8100	137·4450	157·0800	176·7150

APPENDIX IX.

Squares of Numbers 1—1000.

Table of Squares.

No.	0	1	2	3	4	5	6	7	8	9
10	10000	10201	10404	10609	10816	11025	11236	11449	11664	11881
11	12100	12321	12544	12769	12996	13225	13456	13689	13924	14161
12	14400	14641	14884	15129	15376	15625	15876	16129	16384	16641
13	16900	17161	17424	17689	17956	18225	18496	18769	19044	19321
14	19600	19881	20164	20449	20736	21025	21316	21609	21904	22201
15	22500	22801	23104	23409	23716	24025	24336	24649	24964	25281
16	25600	25921	26244	26569	26896	27225	27556	27889	28224	28561
17	28900	29241	29584	29929	30276	30625	30976	31329	31684	32041
18	32400	32761	33124	33489	33856	34225	34596	34969	35344	35721
19	36100	36481	36864	37249	37636	38025	38416	38809	39204	39601
20	40000	40401	40804	41209	41616	42025	42436	42849	43264	43681
21	44100	44521	44944	45369	45796	46225	46656	47089	47524	47961
22	48400	48841	49284	49729	50176	50625	51076	51529	51984	52441
23	52900	53361	53824	54289	54756	55225	55696	56169	56644	57121
24	57600	58081	58564	59049	59536	60025	60516	61009	61504	62001
25	62500	63001	63504	64009	64516	65025	65536	66049	66564	67081
26	67600	68121	68644	69169	69696	70225	70756	71289	71824	72361
27	72900	73441	73984	74529	75076	75625	76176	76729	77284	77841
28	78400	78961	79524	80089	80656	81225	81796	82369	82944	83521
29	84100	84681	85264	85849	86436	87025	87616	88209	88804	89401
30	90000	90601	91204	91809	92416	93025	93636	94249	94864	95481
31	96100	96721	97344	97969	98596	99225	99856	100489	101124	101761
32	102400	103041	103684	104329	104976	105625	106276	106929	107584	108241
33	108900	109561	110224	110889	111556	112225	112896	113569	114244	114921
34	115600	116281	116964	117649	118336	119025	119716	120409	121104	121801
35	122500	123201	123904	124609	125316	126025	126736	127449	128164	128881
36	129600	130321	131044	131769	132496	133225	133956	134689	135424	136161
37	136900	137641	138384	139129	139876	140625	141376	142129	142884	143641
38	144400	145161	145924	146689	147456	148225	148996	149769	150544	151321
39	152100	152881	153664	154449	155236	156025	156816	157609	158404	159201
40	160000	160801	161604	162409	163216	164025	164836	165649	166464	167281
41	168100	168921	169744	170569	171396	172225	173056	173889	174724	175561
42	176400	177241	178084	178929	179776	180625	181476	182329	183184	184041
43	184900	185761	186624	187489	188356	189225	190096	190969	191844	192721
44	193600	194481	195364	196249	197136	198025	198916	199809	200704	201601
45	202500	203401	204304	205209	206116	207025	207936	208849	209764	210681
46	211600	212521	213444	214369	215296	216225	217156	218089	219024	219961
47	220900	221841	222784	223729	224676	225625	226576	227529	228484	229441
48	230400	231361	232324	233289	234256	235225	236196	237169	238144	239121
49	240100	241081	242064	243049	244036	245025	246016	247009	248004	249001
50	250000	251001	252004	253009	254016	255025	256036	257049	258064	259081
51	260100	261121	262144	263169	264196	265225	266256	267289	268324	269361
52	270400	271441	272484	273529	274576	275625	276676	277729	278784	279841
53	280900	281961	283024	284089	285156	286225	287296	288369	289444	290521
54	291600	292681	293764	294849	295936	297025	298116	299209	300304	301401

APPENDIX IX—*contd.*

Squares of Numbers 1—1000—*contd.*

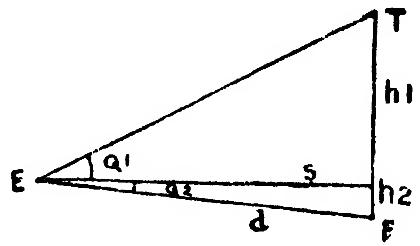
Table of Squares—contd.

No.	0	1	2	3	4	5	6	7	8	9
55	302500	303601	304704	305809	306916	308025	309136	310249	311364	312481
56	313600	314721	315844	316969	318096	319225	320356	321489	322624	323761
57	324900	326041	327184	328329	329476	330625	331776	332929	334084	335241
58	336400	337561	338724	339889	341056	342225	343396	344569	345744	346921
59	348100	349281	350464	351649	352836	354025	355216	356409	357604	358801
60	360000	361201	362404	363609	364816	366025	367236	368449	369664	370881
61	372100	373321	374544	375769	376996	378225	379456	380689	381924	383161
62	384400	385641	386884	388129	389376	390625	391876	393129	394384	395641
63	396900	398161	399424	400689	401956	403225	404496	405769	407044	408321
64	409600	410881	412164	413449	414736	416025	417316	418609	419904	421201
65	422500	423801	425104	426409	427716	429025	430336	431649	432964	434281
66	435600	436921	438244	439569	440896	442225	443556	444889	446224	447561
67	448900	450241	451584	452929	454276	455625	456976	458329	459684	461041
68	462400	463761	465124	466489	467856	469225	470596	471969	473344	474721
69	476100	477481	478864	480249	481636	483025	484416	485809	487204	488601
70	490000	491401	492804	494209	495616	497025	498436	499849	501264	502681
71	504100	505521	506944	508369	509796	511225	512656	514089	515524	516961
72	518400	519841	521284	522729	524176	525625	527076	528529	529984	531441
73	532900	534361	535824	537289	538756	540225	541696	543169	544644	546121
74	547600	549081	550564	552049	553536	555025	556516	558009	559504	561001
75	562500	564001	565504	567009	568516	570025	571536	573049	574564	576081
76	577600	579121	580644	582169	583696	585225	586756	588289	589824	591361
77	592900	594441	595984	597529	599076	600625	602176	603729	605284	606841
78	608400	609961	611524	613089	614656	616225	617796	619369	620944	622521
79	624100	625681	627264	628849	630436	632025	633616	635209	636804	638401
80	640000	641601	643204	644809	646416	648025	649636	651249	652864	654481
81	656100	657721	659344	660969	662596	664225	665856	667489	669124	670761
82	672400	674041	675684	677329	678976	680625	682276	683929	685584	687241
83	688900	690561	692224	693889	695556	697225	698896	700569	702244	703921
84	705600	707281	708964	710649	712336	714025	715716	717409	719104	720801
85	722500	724201	725904	727609	729316	731025	732736	734449	736164	737881
86	739600	741321	743044	744769	746496	748225	749956	751689	753424	755161
87	756900	758641	760384	762129	763876	765625	767376	769129	770884	772641
88	774400	776161	777924	779689	781456	783225	784996	786769	788544	790321
89	792100	793881	795664	797449	799236	801025	802816	804609	806404	808201
90	810000	811801	813604	815409	817216	819025	820836	822649	824464	826281
91	828100	829921	831744	833569	835396	837225	839056	840889	842724	844561
92	846400	848241	850084	851929	853776	855625	857476	859329	861184	863041
93	864900	866761	868624	870489	872356	874225	876096	877969	879844	881721
94	883600	885481	887364	889249	891136	893025	894916	896809	898704	900601
95	902500	904401	906304	908209	910116	912025	913936	915849	917764	919681
96	921600	923521	925444	927369	929296	931225	933156	935089	937024	938961
97	940900	942841	944784	946729	948676	950625	952576	954529	956484	958441
98	960400	962361	964324	966289	968256	970225	972196	974169	976144	978121
99	980100	982081	984064	986049	988036	990025	992016	994009	996004	998001

APPENDIX X.

Determination of the height of a tree with Abney's Level or similar instruments.

A position is taken up such that both top and foot (or cross mark) of the tree are visible and the top is at an angle of 35° to 50°. The angles are then read to the top θ_1, and foot (or cross mark) θ_2, and the distance d measured in a straight line from the latter to the eyepiece of the instrument.



The horizontal distance s to the tree is then d sin $(90\text{-}\theta_2)$.
The height h_1 above the horizontal line is s tan θ_1.
The height h_2 below the horizontal line is s tan θ_2.
Total height, H, is h_1+h_2.

Notes.

1. If the tree is leaning, the position chosen should be in the same vertical plane as the axis of the tree. An estimate is made of the horizontal projection p of the leaning stem and p tan θ_1 is deducted from H calculated as usual. This of course gives the vertical height of the tip above the base, not the length of the stem.

2. The cross mark gives a better intersection than the foot of a tree, and should be used, the additional height, normally $4\frac{1}{2}'$, being added in at the end.

3. If the stand supplied with an Abney's level is used, it will be found that the eye of the observer is considerably lower for the upward reading than the downward. The difference of the two positions (usually about 2′) is measured and deducted from the total height.

4. The computations are much simplified if the position is so selected that $\theta_1=45°$, when $h_1=s$, and if $\theta_2=0°$ when $h_2=0$.

5. Tables are given on the following pages for natural sines and tangents for whole degrees and intervals of 10′ corresponding to the usual graduation of the instruments used. It will be remembered that $\cos\theta=\sin(90°-\theta)$ and that $\tan\theta=\frac{1}{\cot\theta}$

6. The necessary computations can all be readily made on the 10″ slide rule with the degree of accuracy usually required, without reference to tables.

Ex. 41. $\theta_1=42°$; $\theta_2=12°$; d=72′: F *is at cross mark at normal b.h.; the two positions of the instrument are 2′ apart in a vertical line; the tree leans towards the observer, its horizontal projection being estimated at 8′.*

$s=d\sin(90\text{-}\theta_2)=d\ \sin 78=72\times\cdot9781=70\cdot4.$
$h_1=s\tan\theta_1\qquad=70\cdot4\times\cdot9004=63\cdot4.$
$h_2=s\tan\theta_2\qquad=70\cdot4\times\cdot2126=15\cdot0.$
$H\qquad=63\cdot4+15\cdot0=78\cdot4.$
$p\tan\theta_1=8\times\tan 42=8\times\cdot9004=7\cdot2.$
Vertical height of tree = $78\cdot4+4\cdot5-2\cdot0-7\cdot2=73\cdot7$ ft.

Natural Sines.

	0′	10′	20′	30′	40′	50′		0′	10′	20′	30′	40′	50′
0°	0·0000	0·0029	0·0058	0·0087	0·0116	0·0145	45°	0·7071	0·7092	0·7112	0·7133	0·7153	0·7173
1	0175	0204	0233	0262	0291	0320	46	7193	7214	7234	7254	7274	7294
2	0349	0378	0407	0436	0465	0494	47	7314	7333	7353	7373	7392	7412
3	0523	0552	0581	0610	0640	0669	48	7431	7451	7470	7490	7509	7528
4	0698	0727	0756	0785	0814	0843	49	7547	7566	7585	7604	7623	7642
5	0872	0901	0929	0958	0987	1016	50	7660	7679	7698	7716	7735	7753
6	1045	1074	1103	1132	1161	1190	51	7771	7790	7808	7826	7844	7862
7	1219	1248	1276	1305	1334	1363	52	7880	7898	7916	7934	7951	7969
8	1392	1421	1449	1478	1507	1536	53	7986	8004	8021	8039	8056	8073
9	1564	1593	1622	1650	1679	1708	54	8090	8107	8124	8141	8158	8175
10	1736	1765	1794	1822	1851	1880	55	8192	8208	8225	8241	8258	8274
11	1908	1937	1965	1994	2022	2051	56	8290	8307	8323	8339	8355	8371
12	2079	2108	2136	2164	2193	2221	57	8387	8403	8418	8434	8450	8465
13	2250	2278	2306	2334	2363	2391	58	8480	8496	8511	8526	8542	8557
14	2419	2447	2476	2504	2532	2560	59	8572	8587	8601	8616	8631	8646
15	2588	2616	2644	2672	2700	2728	60	8660	8675	8689	8704	8718	8732
16	2756	2784	2812	2840	2868	2896	61	8746	8760	8774	8788	8802	8816
17	2924	2952	2979	3007	3035	3062	62	8829	8843	8857	8870	8884	8897
18	3090	3118	3145	3173	3201	3228	63	8910	8923	8936	8949	8962	8975
19	3256	3283	3311	3338	3365	3393	64	8988	9001	9013	9026	9038	9051
20	3420	3448	3475	3502	3529	3557	65	9063	9075	9088	9100	9112	9124
21	3584	3611	3638	3665	3692	3719	66	9135	9147	9159	9171	9182	9194
22	3746	3773	3800	3827	3854	3881	67	9205	9216	9228	9239	9250	9261
23	3907	3934	3961	3987	4014	4041	68	9272	9283	9293	9304	9315	9325
24	4067	4094	4120	4147	4173	4200	69	9336	9346	9356	9367	9377	9387
25	4226	4253	4279	4305	4331	4358	70	9397	9407	9417	9426	9436	9446
26	4384	4410	4436	4462	4488	4514	71	9455	9465	9474	9483	9492	9502
27	4540	4566	4592	4617	4643	4669	72	9511	9520	9528	9537	9546	9555
28	4695	4720	4746	4772	4797	4823	73	9563	9572	9580	9588	9596	9605
29	4848	4874	4899	4924	4950	4975	74	9613	9621	9628	9636	9644	9652
30	5000	5025	5050	5075	5100	5125	75	9659	9667	9674	9681	9689	9696
31	5150	5175	5200	5225	5250	5275	76	9703	9710	9717	9724	9730	9737
32	5299	5324	5348	5373	5398	5422	77	9744	9750	9757	9763	9769	9775
33	5446	5471	5495	5519	5544	5568	78	9781	9787	9793	9799	9805	9811
34	5592	5616	5640	5664	5688	5712	79	9816	9822	9827	9833	9838	9843
35	5736	5760	5783	5807	5831	5854	80	9848	9853	9858	9863	9868	9872
36	5878	5901	5925	5948	5972	5995	81	9877	9881	9886	9890	9894	9899
37	6018	6041	6065	6088	6111	6134	82	9903	9907	9911	9914	9918	9922
38	6157	6180	6202	6225	6248	6271	83	9925	9929	9932	9936	9939	9942
39	6293	6316	6338	6361	6383	6406	84	9945	9948	9951	9954	9957	9959
40	6428	6450	6472	6494	6517	6539	85	9962	9964	9967	9969	9971	9974
41	6561	6583	6604	6626	6648	6670	86	9976	9978	9980	9981	9983	9985
42	6691	6713	6734	6756	6777	6799	87	9986	9988	9989	9990	9992	9993
43	6820	6841	6862	6884	6905	6926	88	9994	9995	9996	9997	9997	9998
44	6947	6967	6988	7009	7030	7050	89	9998	9999	9999	1·0000	1·0000	1·0000

Natural Tangents.

	0′	10′	20′	30′	40′	50′		0′	10′	20′	30′	40′	50′
0°	0·0000	0·0029	0·0058	0·0087	0·0116	0·0145	45°	1·0000	1·0058	1·0117	1·0176	1·0235	1·0295
1	·0175	·0204	·0233	·0262	·0291	·0320	46	1·0355	1·0416	1·0477	1·0538	1·0599	1·0661
2	·0349	·0378	·0407	·0437	·0466	·0495	47	1·0724	1·0786	1·0850	1·0913	1·0977	1·1041
3	·0524	·0553	·0582	·0612	·0641	·0670	48	1·1106	1·1171	1·1237	1·1303	1·1369	1·1436
4	·0699	·0729	·0758	·0787	·0816	·0846	49	1·1504	1·1571	1·1640	1·1708	1·1778	1·1847
5	·0875	·0904	·0934	·0963	·0992	·1022	50	1·1918	1·1988	1·2059	1·2131	1·2203	1·2276
6	·1051	·1080	·1110	·1139	·1169	·1198	51	1·2349	1·2423	1·2497	1·2572	1·2647	1·2723
7	·1228	·1257	·1287	·1317	·1346	·1376	52	1·2799	1·2876	1·2954	1·3032	1·3111	1·3190
8	·1405	·1435	·1465	·1495	·1524	·1554	53	1·3270	1·3351	1·3432	1·3514	1·3597	1·3680
9	·1584	·1614	·1644	·1673	·1703	·1733	54	1·3764	1·3848	1·3934	1·4019	1·4106	1·4193
10	·1763	·1793	·1823	·1853	·1883	·1914	55	1·4281	1·4370	1·4460	1·4550	1·4641	1·4733
11	·1944	·1974	·2004	·2035	·2065	·2095	56	1·4826	1·4919	1·5013	1·5108	1·5204	1·5301
12	·2126	·2156	·2186	·2217	·2247	·2278	57	1·5399	1·5497	1·5597	1·5697	1·5798	1·5900
13	·2309	·2339	·2370	·2401	·2432	·2462	58	1·6003	1·6107	1·6212	1·6319	1·6426	1·6534
14	·2493	·2524	·2555	·2586	·2617	·2648	59	1·6643	1·6753	1·6864	1·6977	1·7090	1·7205
15	·2679	·2711	·2742	·2773	·2805	·2836	60	1·7321	1·7437	1·7556	1·7675	1·7796	1·7917
16	·2867	·2899	·2931	·2962	·2994	·3026	61	1·8040	1·8165	1·8291	1·8418	1·8546	1·8676
17	·3057	·3089	·3121	·3153	·3185	·3217	62	1·8807	1·8940	1·9074	1·9210	1·9347	1·9486
18	·3249	·3281	·3314	·3346	·3378	·3411	63	1·9626	1·9768	1·9912	2·0057	2·0204	2·0353
19	·3443	·3476	·3508	·3541	·3574	·3607	64	2·0503	2·0655	2·0809	2·0965	2·1123	2·1283
20	·3640	·3673	·3706	·3739	·3772	·3805	65	2.1445	2·1609	2·1775	2·1943	2·2113	2·2286
21	·3839	·3872	·3906	·3939	·3973	·4006	66	2·2460	2·2637	2·2817	2·2998	2·3183	2·3369
22	·4040	·4074	·4108	·4142	·4176	·4210	67	2·3559	2·3750	2·3945	2·4142	2·4342	2·4545
23	·4245	·4279	·4314	·4348	·4383	·4417	68	2·4751	2·4960	2·5172	2·5386	2·5605	2·5826
24	·4452	·4487	·4522	·4557	·4592	·4628	69	2·6051	2·6279	2·6511	2·6746	2·6985	2·7228
25	·4663	·4699	·4734	·4770	·4806	·4841	70	2·7475	2·7725	2·7980	2·8239	2·8502	2·8770
26	·4877	·4913	·4950	·4986	·5022	·5059	71	2·9042	2·9319	2·9600	2·9887	3·0178	3·0475
27	·5095	·5132	·5169	·5206	·5243	·5280	72	3·0777	3·1084	3·1397	3·1716	3·2041	3·2371
28	·5317	·5354	·5392	·5430	·5467	·5505	73	3·2709	3·3052	3·3402	3·3759	3·4124	3·4495
29	·5543	·5581	·5619	·5658	·5696	·5735	74	3·4874	3·5261	3·5656	3·6059	3·6470	3·6891
30	·5774	·5812	·5851	·5890	·5930	·5969	75	3·7321	3·7760	3·8208	3·8667	3·9136	3·9617
31	·6009	·6048	·6088	·6128	·6168	·6208	76	4·0108	4·0611	4·1126	4·1653	4·2193	4·2747
32	·6249	·6289	·6330	·6371	·6412	·6453	77	4·3315	4·3897	4·4494	4·5107	4·5736	4·6382
33	·6494	·6536	·6577	·6619	·6661	·6703	78	4·7046	4·7729	4·8430	4·9152	4·9894	5·0658
34	·6745	·6787	·6830	·6873	·6916	·6959	79	5·1446	5·2257	5·3093	5·3955	5·4845	5·5764
35	·7002	·7046	·7089	·7133	·7177	·7221	80	5·6713	5·7694	5·8708	5·9758	6·0844	6·1970
36	·7265	·7310	·7355	·7400	·7445	·7490	81	6·3138	6·4348	6·5606	6·6912	6·8269	6·9682
37	·7536	·7581	·7627	·7673	·7720	·7766	82	7·1154	7·2687	7·4287	7·5958	7·7704	7·9530
38	·7813	·7860	·7907	·7954	·8002	·8050	83	8·1443	8·3450	8·5555	8·7769	9·0098	9·2553
39	·8098	·8146	·8195	·8243	·8292	·8342	84	9·5144	9·7882	10·0780	10·3854	10·7119	11·0594
40	·8391	·8441	·8491	·8541	·8591	·8642	85	11·4301	11·8262	12·2505	12·7062	13·1969	13·7267
41	·8693	·8744	·8796	·8847	·8899	·8952	86	14·3007	14·9244	15·6048	16·3499	17·1693	18·0750
42	·9004	·9057	·9110	·9163	·9217	·9271	87	19·0811	20·2056	21·4704	22·9038	24·5418	26·4316
43	·9325	·9380	·9435	·9490	·9545	·9601	88	28·6363	31·2416	34·3678	38·1885	42·9641	49·1039
44	·9657	·9713	·9770	·9827	·9884	·9942	89	57·2900	68·7501	85·9398	114·5887	171·8854	343·7737

APPENDIX XI.

Useful Constants and Formulæ.

1. *English measures.*

1 mile = 80 chains = 80 × 22 yards = 5280 ft.
1 acre = 4840 sq. yard = 43560 sq. ft.
1 sq. mile = 640 acres.
1 ton = 2240 lbs. = 50 c.ft. (for transport, etc.).
1 gallon = 4 quarts = 8 pints = 10 lbs. water = 277 c. ins. = ·160 c.ft.
1 c.ft. = 6¼ galls. = 1000 ozs. water = 62½ lbs.

2. *Relation of English and metric measures.*

1 inch = 25·4 m.m. (25·399978).
1 foot = 0·305 metre (0·304800).
1 yard = 0·914 metre (0·914399).
1 mile = 1·609 kilometres (1·609343).
(Approximately eight fifths.)
1 acre = 0·405 hectare (0·40468).
1 sq. ft. = 0·093 sq. metre (0·092903).
1 c. ft. = 0·028 c. metre (0·028317).
1 lb. = 453·592 grams.
1 sq. ft. per acre = 0·230 sq. metre per hectare.
1 c.ft. per acre = 0·070 c. metre per hectare.

1 metre = 39·4 ins (39·370113).
,, = 3·28 feet (3·280843).
,, = 1·094 yards (1·093614).
1 kilometre = 0·621 mile (0·621372).
(Approximately five eighths).
1 hectare = 2·471 acre (2·47109).
1 sq. metre = 10·764 sq. ft. (10·763931).
1 c. metre = 35·316 c. ft. (35·315617).
1 kilogram = 2·205 lbs.
1 sq. metre per hectare = 4·356 sq. ft. per acre.
1 c. metre per hectare = 14·291 c.ft. per acre.

	Cubic metres to Cubic feet.	Cubic feet to Cubic metres.	Cubic feet per acre to Cubic metres per hectare.	Cubic metre per hectare to Cubic feet per acre.	Centimetres to Inches.	Inches to Centimetres.
1.	35·3156	0·028	0·0700	14·291	0·3937	2·540
2.	70·6312	0·057	0·1399	28·582	0·7874	5·080
3.	105·9469	0·085	0·2099	42·874	1·1811	7·620
4.	141·2625	0·113	0·2799	57·165	1·5748	10·160
5.	176·5781	0·142	0·3499	71·456	1·9685	12·700
6.	211·8937	0·170	0·4198	85·747	2·3622	15·240
7.	247·2093	0·198	0·4898	100·038	2·7559	17·780
8.	282·5249	0·227	0·5598	114·329	3·1496	20·320
9.	317·8406	0·255	0·6298	128·621	3·5433	22·860

3. *Relation of Indian measures to English.*

1 Chittack = 2 ounces.
1 seer = 16 chittacks = 2·05 lbs.
1 maund = 40 seers = 82 lbs.

4. *Mathematical Constants.*

$\pi = 3{\cdot}14159$ . . Base of Napierian logarithms, $e = 2{\cdot}71828$.

$\frac{1}{\pi} = 0{\cdot}31831$ . . Multiplier for conversion of common into Napierian logarithms $= 2{\cdot}30259$.

$\pi^2 = 9{\cdot}86959$ . . Multiplier for conversion of Napierian into common logarithms $= 0{\cdot}43429$.

5. *Algebraic Formulæ.*

Solution of equation $ax^2+bx+c=0$: $x = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$.

Sum of n terms of an arithmetic progression $= [2a + (n-1)d]\frac{n}{2}$

Sum of n terms of a geometric progression $= a\frac{r^n-1}{r-1}$

Combinations of n things taken r at a time $= \frac{n(n-1)(n-2)..(n-r+1)}{\underline{|r}}$

Permutations of n things recurring $p, q, r..$times $= \frac{\underline{|n}}{\underline{|p}\,\underline{|q}\,\underline{|r}..}$

6. *Geometrical Formulæ.*

Area of a triangle when s = half the sum of the sides $= \sqrt{s(s-a)(s-b)(s-c)}$.

Area of a circle $= \pi r^2 = \frac{\pi d^2}{4} = \frac{g^2}{4\pi}$.

Curved surface of a cylinder $= 2\pi rh$.

Curved surface of a cone $= \pi r\sqrt{r^2+h^2} = \pi r(l+r)$, where l = slant height.

Curved surface of a sphere $= 4\pi r^2$

Volume of a cylinder $= \pi r^2 h$.

" " cone $= \frac{1}{3}\pi r^2 h$.

" " sphere $= \frac{4}{3}\pi r^3$.

7. *Spacing for given number of trees per acre* (arranged in squares).

Number.	Distance. ft.	Number.	Distance. ft.	Number.	Distance. ft.	Number.	Distance. ft.	Number.	Distance. ft.
1 . .	209	10	66	55	28	100	21	1000	6·6
2 . .	148	15	54	60	27	200	15	1100	6·3
3 . .	121	20	47	65	26	300	12	1200	6·0
4 . .	104	25	42	70	25	400	10	1300	5·8
5 . .	93	30	38	75	24	500	9·3	1400	5·6
6 . .	85	35	35	80	23	600	8·5	1500	5·4
7 . .	79	40	33	85	23	700	7·9	1600	5·2
8 . .	74	45	31	90	22	800	7·4	1800	4·9
9 . .	70	50	29	95	21	900	7·0	2000	4·7

APPENDIX XII.

NOTE ON OFFICE PROCEDURE.

(i) *Forms.*

The following standardised forms should be used for the statistical work described in this volume.

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Indents for Forest Research Institute special forms required should be sent in to the Central Silviculturist annually by December 15th, supplies being expected in the following July.

A copy of Sample Plot Form 9 (List of plots) should be supplied to every Divisional Forest Officer for the plots in his division, with such additional notes as may be considered advisable.

(ii) *Files.*

Complete files of all sample plots should be sent to the Central Silviculturist after laying out or remeasurement, for calculation and copying. If their return is desired by any particular date, it should be noted. Computations are mostly done between July and December.

Records of other statistical investigations should also be sent in when calculations are required with a note as to what is wanted.

Plot files may be filed by species according to Howard's system, but it may be found more convenient in connection with field work to file them by divisions in provincial offices.

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